Brighter than a Thousand Suns

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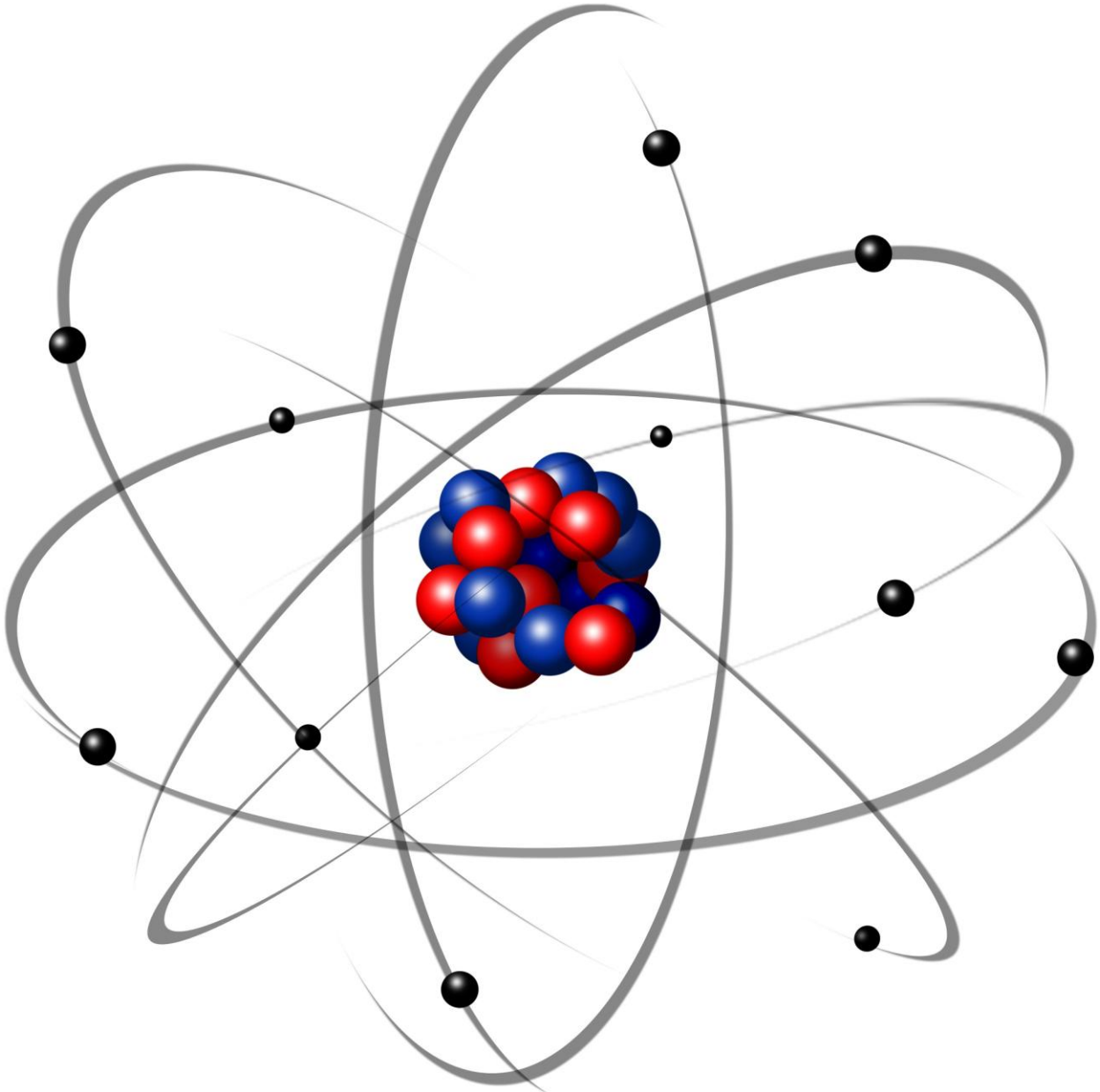

Brighter than a Thousand Suns

How curiosity about the natural world inadvertently led Science to stumble upon one of the most dangerous discoveries that has ever been made.

A Review of the Manhattan Project

Interdisciplinary Unit:
A Scientific Perspective on the History of the Atomic Bomb

History ↔ Science

- How Science shapes History.
- How History determines the future path of Science.

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Conceptual Lenses

• **Question:** How are *conflict* and *change* defined?

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Conceptual Lenses

- **Answer:** Conflict

Conflict arises from differences in opinions and / or principles. Conflict can be emotional and / or physical. Conflict may exist within a single person, or between large nations.

- **Answer:** Change

Change is inevitable. Change occurs as things become different over time. Change can be positive (good) or negative (bad). Change can be planned or unexpected. Change can be linear or cyclic.

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1. What events mark key moments in human history?

2. What drives scientific innovation? Would the Manhattan Project have taken place during peacetime?

3. How could people of conscience create weapons of mass destruction?

4. What is the purpose of Science?

5. What responsibilities does Science have to society?

6. Who determines what Science should do?

7. What are some positive outcomes from research into atomic weapons?

8. Is it acceptable to do Science for the sake of curiosity, without any care for the consequences?

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The beginning…

…of events that changed the world forever.

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- The discovery of *nuclear fission* by German Chemists Otto Hahn (Nobel Prize in Chemistry, 1944) and Fritz Strassmann in 1938 made development of an *atomic bomb* a theoretical possibility.

- Lise Meitner's (pictured) contribution to the work was not recognised by the Nobel Prize Committee, or in Otto Hahn's acceptance speech.

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- **Question:** What *internal conflict* do you imagine Otto Hahn had to come to terms with after learning about America's use of nuclear weapons against Japan?

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- **Answer:** Although he was not directly involved with the development of any nuclear weapons, Otto Hahn felt personally responsible for the deaths resulting from the atomic bombs that were dropped on Hiroshima and Nagasaki.

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- Chemical element 109 – *Meitnerium* – is named in honour of Lise Meitner's outstanding contribution to Science.

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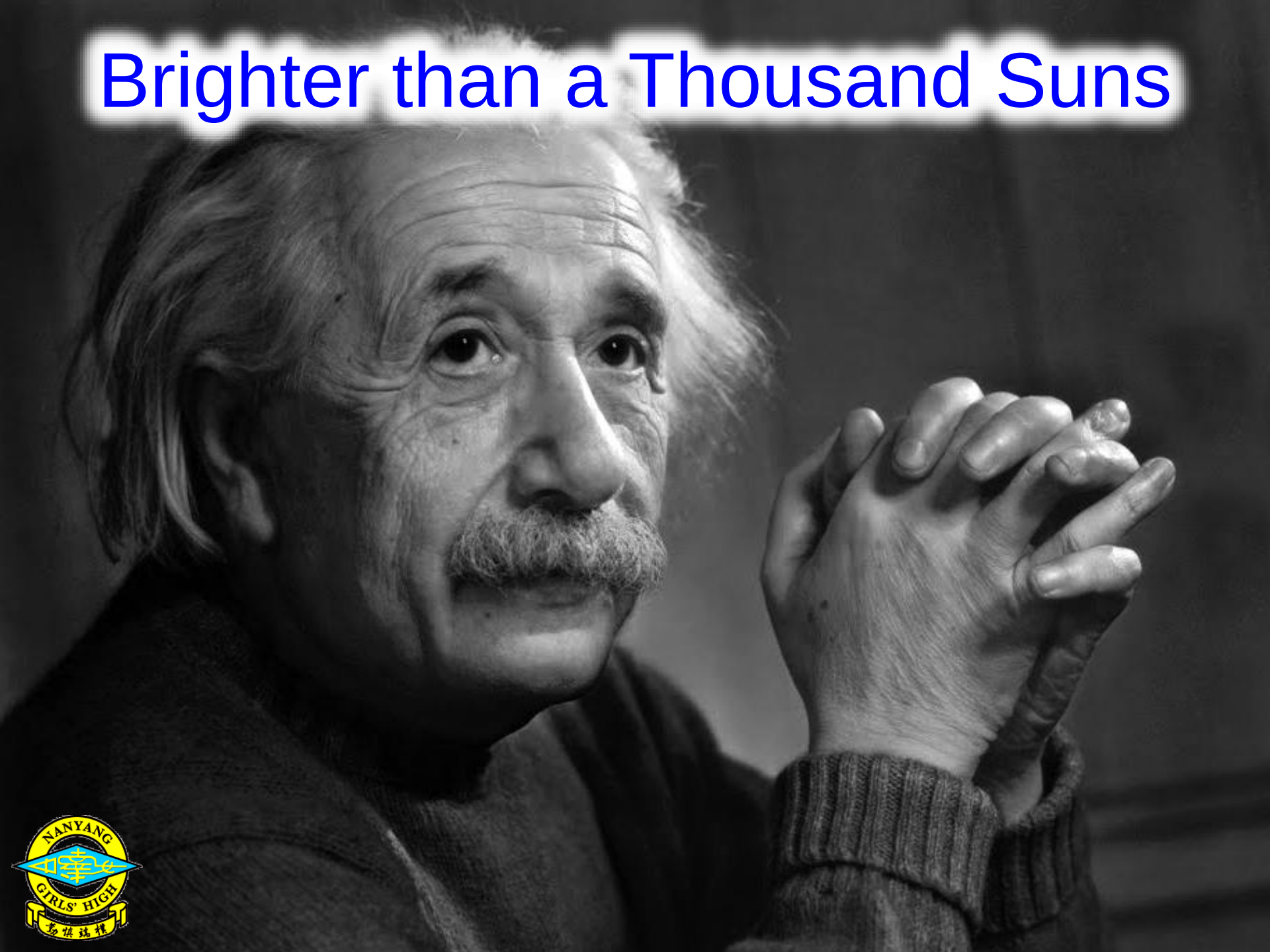

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- Scientists recognised the potential for nuclear fission to create enormous amounts of energy. This energy could be used peacefully, or could be used to create " *bombs with a destructiveness vastly greater than anything now known* ".

- In August 1939 a letter, signed by *Albert Einstein* (Nobel Prize in Physics, 1921), was delivered to Franklin D. Roosevelt.

- **Question:** What do you think Albert Einstein urged the United States Government to do?

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- **Answer:** Einstein urged Roosevelt to secure a source of uranium for the United States. He also urged for research into nuclear fission to be sped-up and scaled-up, with help from industry. It was essential the Allies should develop the first atomic bomb before their aggressors.

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by

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- *The Manhattan Project* was a collaboration between the United States of America, Canada and England to build the world's first atomic bomb. The project began in earnest in 1939.

- *Robert Oppenheimer* led the team of Scientists working on the project, while Major General *Leslie Groves* was in-charge of the military.

- The Manhattan Project prioritised Enrico Fermi's (Nobel Prize in Physics, 1938) construction of a *nuclear fission reactor* to synthesise plutonium from uranium.

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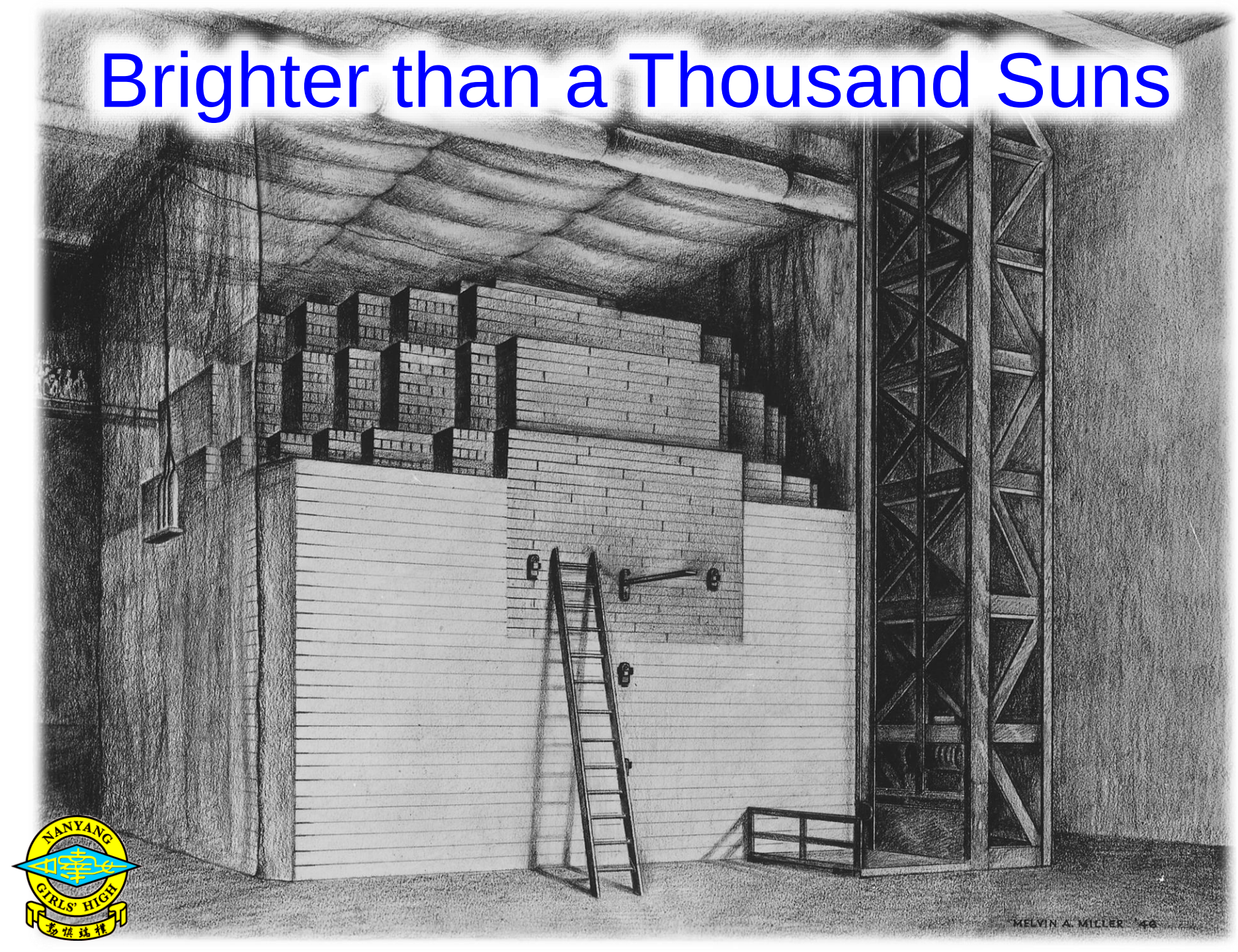

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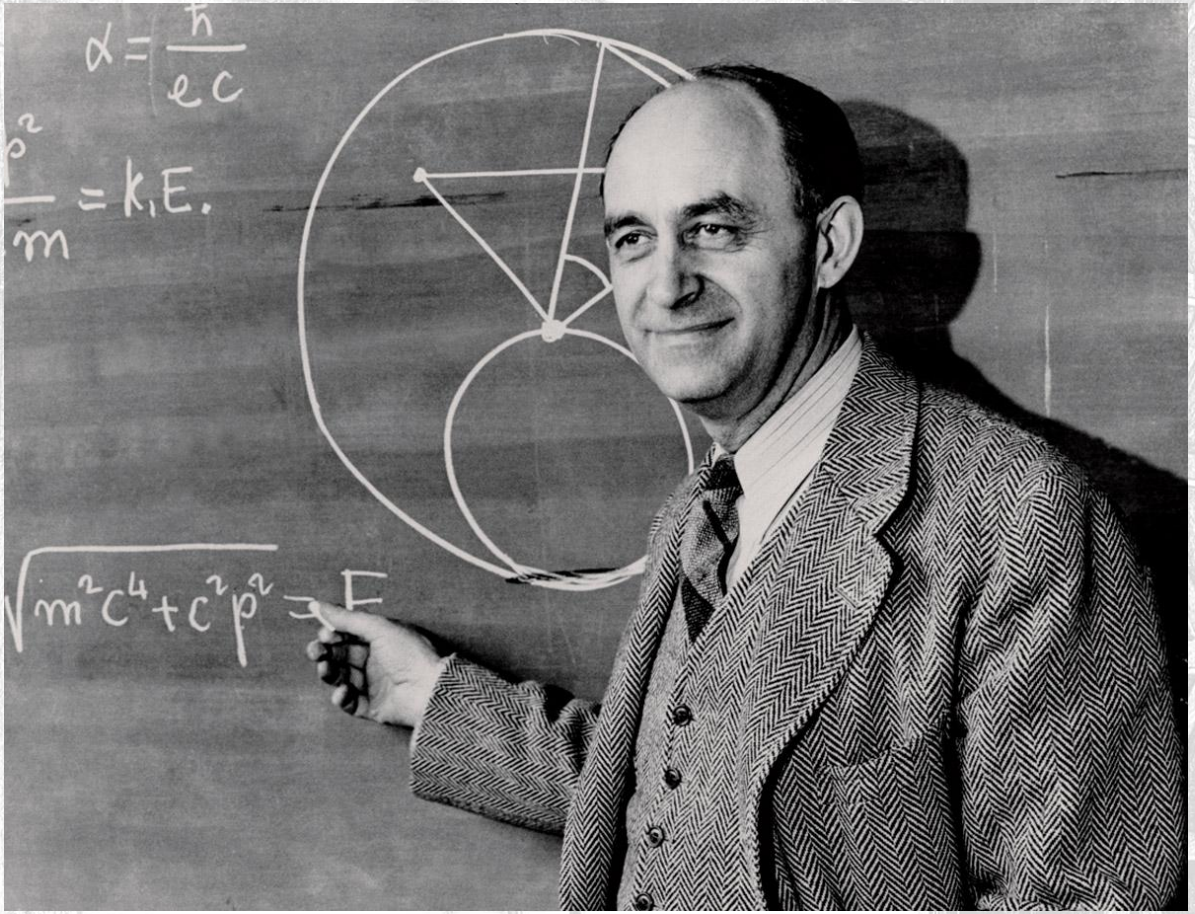

- Enrico Fermi (Nobel Prize in Physics, 1938).

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- The first human-made self-sustaining nuclear chain-reaction was initiated on 2nd December 1942 at the University of Chicago, USA, in an experiment led by the Physicist Enrico Fermi.

- The reactor was built on a squash court under the stands at one of the university's sports fields.

- **Question:** What does the location of the reactor tell you about the Scientist's and United States Government's approach to the Manhattan Project?

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- **Answer:** To build an untested nuclear fission reactor, which has the potential to *melt down* (imagine the Chernobyl nuclear disaster) in a highly populated area shows the urgency with which the Allies were trying to develop the world's first atomic bomb.

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- **Question:** How does such a relatively small mass of radioactive material produce such an enormous amount of energy?

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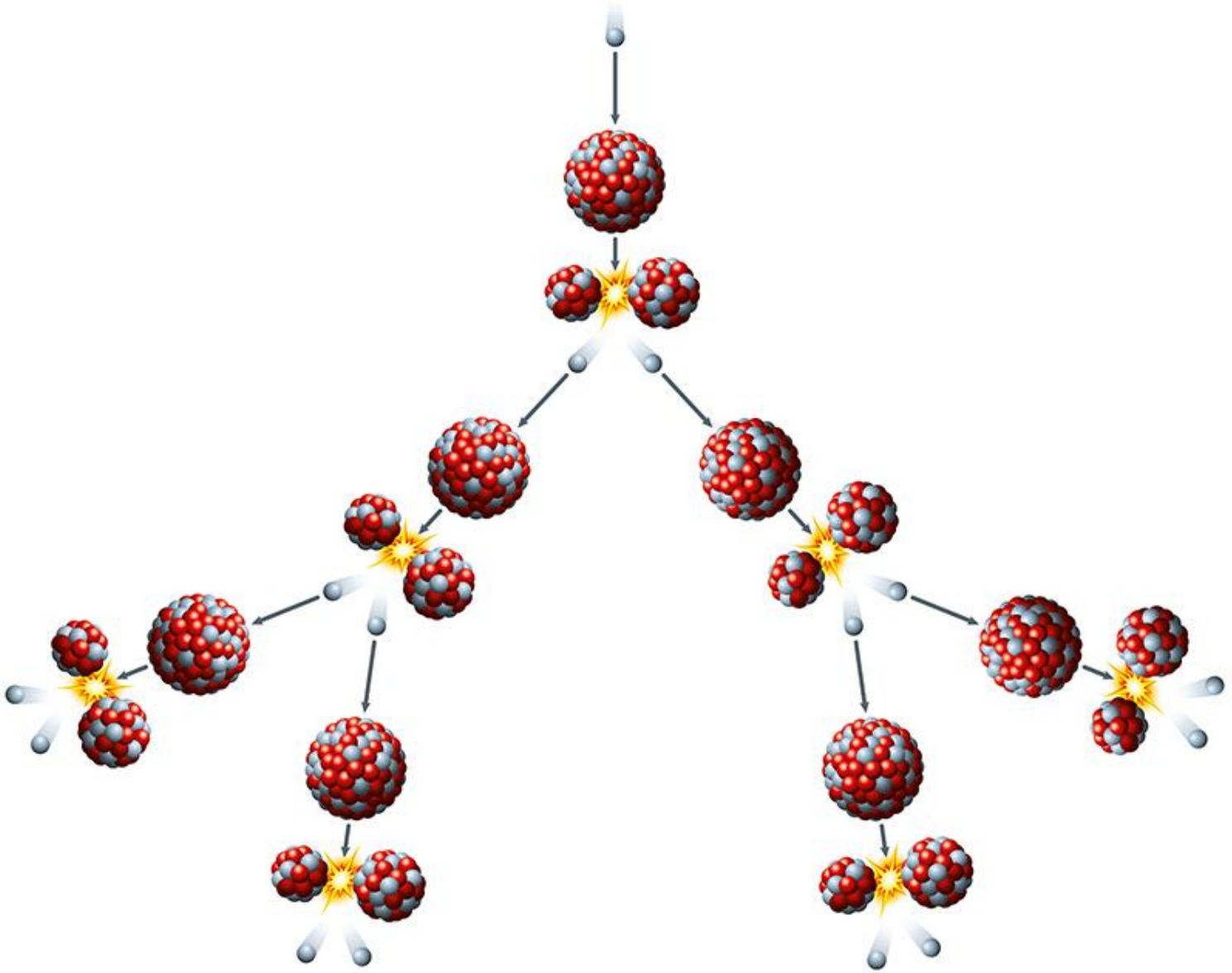

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- **Answer:** What it is *not*:

It is *not* the result of a *chemical reaction*.
It is *not* the result of *nuclear fusion*.

- When the nucleus of a ^{235}U atom is struck by a neutron it undergoes *fission*, forming two stable nuclei, *more neutrons* and *energy*.

- If ^{235}U is of a sufficiently *high purity* (referred to as *weapons grade*) and exceeds a certain *critical mass*, then the *fission* of one ^{235}U nucleus will result in a *chain-reaction*, that releases an enormous amount of *energy*.

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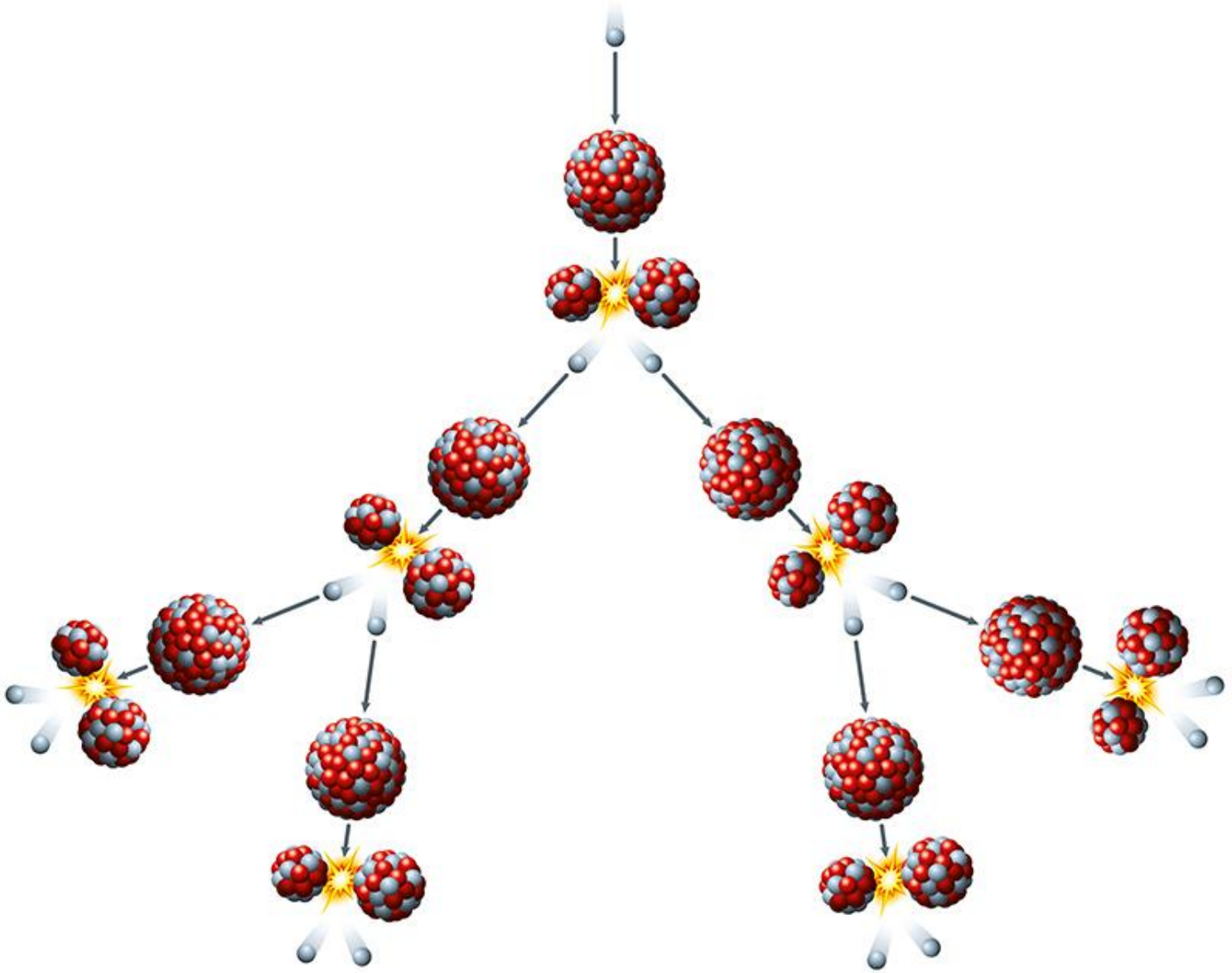

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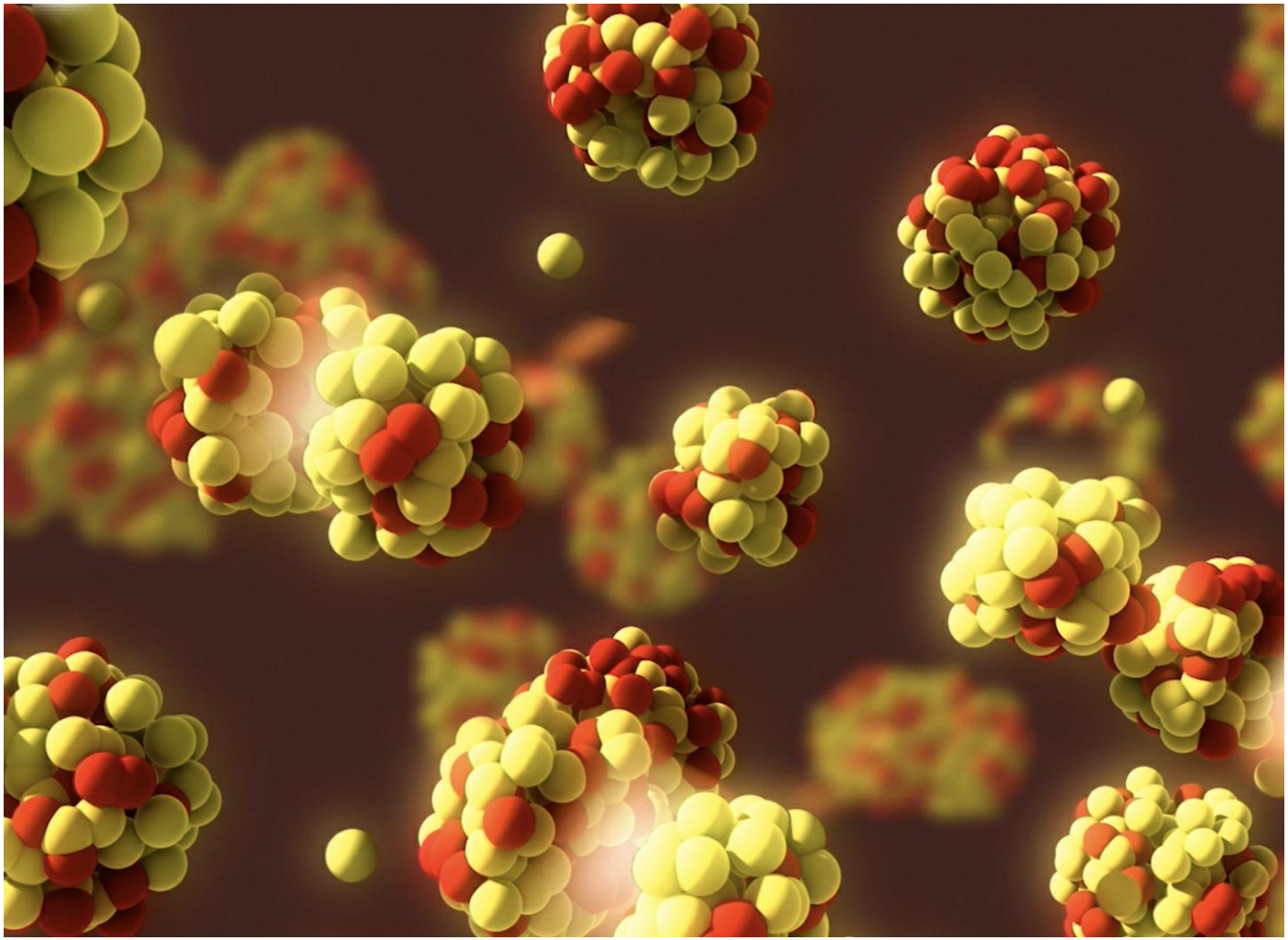

- Video: Animation of Nuclear Fission – 19 sec.

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- Video: Simulation of a Nuclear Chain Reaction – 1 min. 51 sec.

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- When the nucleus of a ^{235}U atom is struck by a neutron and undergoes fission, *0.1% of its mass is converted into energy*.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2\,{}^{1}_{0}n$$

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

- The energy that is released can be calculated using Einstein's famous equation…

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- The energy that is released can be calculated using Einstein's famous equation… …$E = mc^2$

E = energy / joules

m = mass / kilograms

c = speed of light = 300 000 000 ms^{-1}

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- Energy is released in the form of kinetic energy (motion of the particles) and electromagnetic radiation (gamma rays or γ-rays).

- According to Einstein's equation $E = mc^2$, one kilogram of ^{235}U, when converted into pure energy, will release…

…the same amount of energy as detonating 21 500 000 000 kg of conventional explosive…

…the same amount of energy as burning 2 630 000 000 l of petrol.

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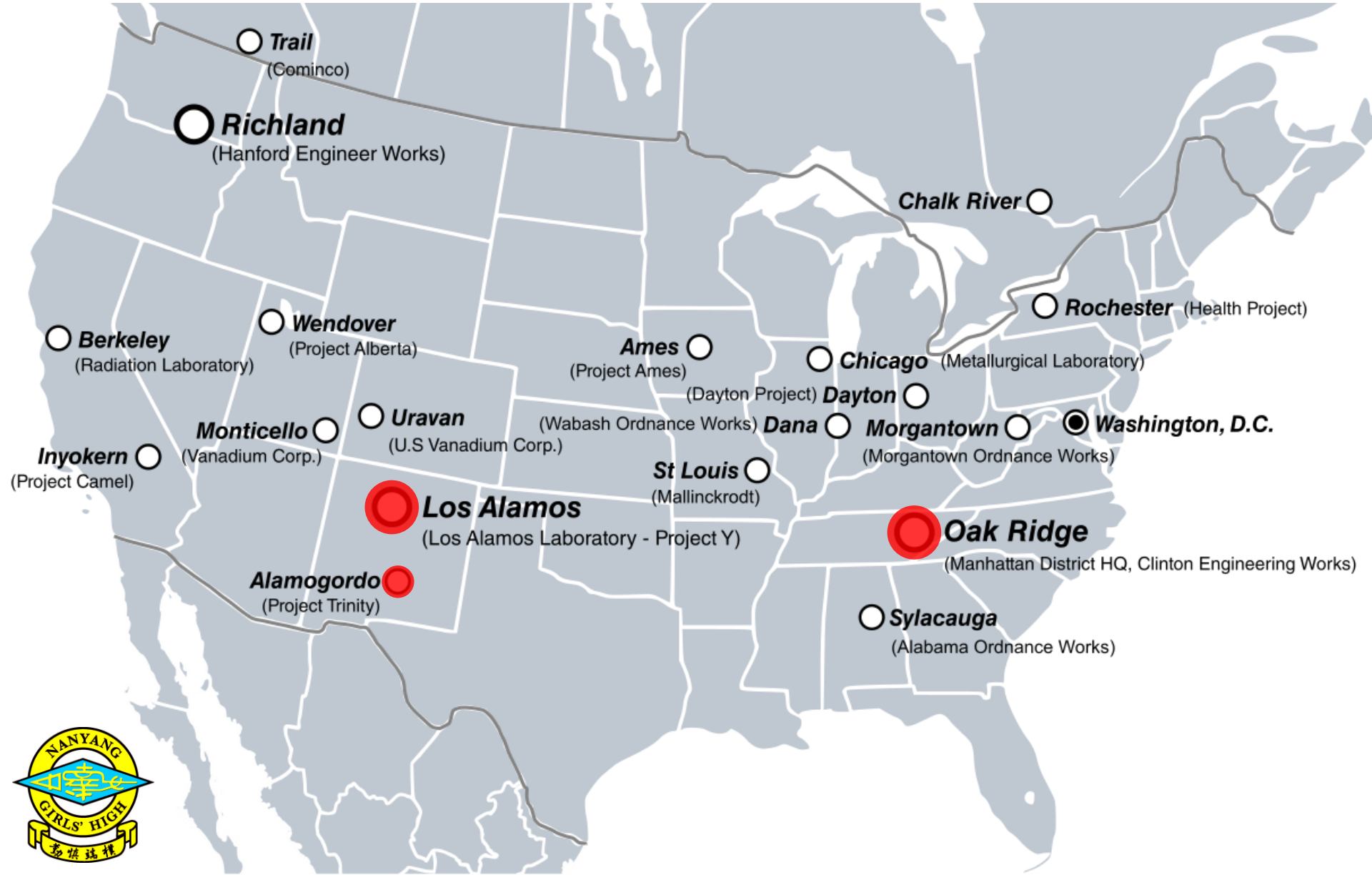

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- **Question:** Why was the Manhattan Project spread over so many different locations?

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- **Answer:** The Manhattan Project was *top secret*. The research and industrial manufacturing were spread widely over many different locations in order to make it impossible for anybody to piece together what was happening and how it was happening. Even workers at specific locations did not know exactly what they were working on, except that it was something to help with the war effort. This had some negative consequences on moral.

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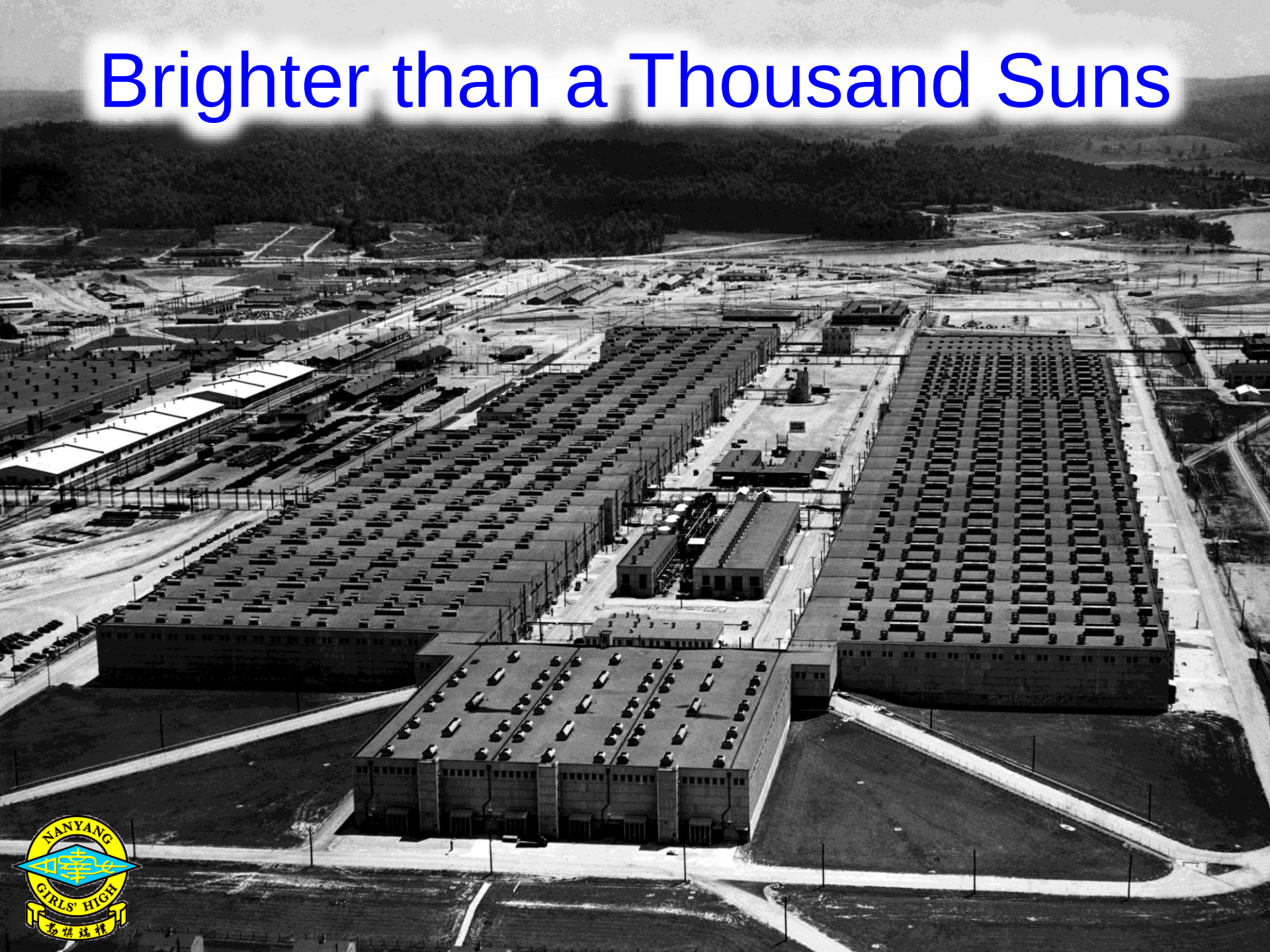

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- The vast K-25 Plant, part of the Oak Ridge site of the Manhattan Project.
- Uranium is a mixture of ^{235}U (0.7%) and ^{238}U (99.3%), but only the ^{235}U isotope is *fissile*.
- The first atomic bomb required 56 kg (critical mass) of weapons grade (85% pure) ^{235}U.
- In order to purify the ^{235}U isotope, uranium was converted into gaseous uranium(VI) fluoride, UF_6.
- **Question:** How could you separate $^{235}UF_6(g)$ from $^{238}UF_6(g)$?

Hint: M_r $^{235}UF_6$ = 349 and M_r $^{238}UF_6$ = 352.

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- **Answer:** One method used to separate the lighter ^{235}U isotope from the heavier ^{238}U isotope was *gaseous diffusion*.

- Uranium was converted into uranium(VI) fluoride. In the gaseous state, the *lighter molecules* of $^{235}UF_6$ *diffuse faster* than the heavier molecules of $^{238}UF_6$.

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Oak Ridge Has Over 425 Buildings

ATOMIC SUPER-BOMB, MADE AT OAK RIDGE, STRIKES JAPAN

By CHILES COLEMAN
United Press Staff Correspondent

WASHINGTON, Aug. 6—The United States has unleashed against Japan the terror of an atomic bomb 2000 times more powerful than the biggest blockbusters ever used in warfare.

President Truman revealed this great scientific achievement today and warned the Japanese that they now face "a rain of ruin from the air the like of which has never been seen on this earth."

More and more of these devastating bombs, unlocking the vast hidden energy that lies within the atom, will tumble on Japan if they continue to reject the Potsdam surrender ultimatum.

The new atomic bomb was used for the first time yesterday. An American plane dropped one on the Japanese army base at Hiroshima.

Its use marked victory for the Allies in the greatest scientific role in history. We put $2,000,000,000 and the work of 125,000 persons into the project.

A single bomb has more power than 20,000 tons of TNT. It has more than 2000 times the blast power of the British "grand slam" volcano bomb, the largest ever used previously in the history of warfare.

Secretary of War Henry L. Stimson disclosed that an improved bomb would be forthcoming shortly that would increase by several-fold the present effectiveness of the new weapon.

Thick Cloud Obscures Target Area

The War Department said it was not yet able to make an accurate report of the damage caused by the first bomb.

"Reconnaissance planes state that an impenetrable cloud of dust and smoke covered the target area," an announcement said. "As soon as accurate details of the result of the bombing become available, they will be released by the secretary of War."

Development of the bomb, a victory of American scientists in a desperate race with Germany, is "the greatest achievement of organized science in history," Mr. Truman said in a statement released at the White House.

The United States, he added, is now prepared "to obliterate more rapidly and completely every productive enterprise the Japanese have above ground in any city.

Japan Warned in Potsdam Ultimatum

He revealed that the July 26 ultimatum issued to Japan

Mr. Truman said that Secretary of War Henry L. Stimson, who has kept in personal touch with the atomic developments, would make public further details. Stimson's statement, the President said, will give "facts" concerning the atomic production centers at Oak Ridge, near Knoxville, Tenn.; at Richland, near Pasco, Wash.; and near Santa Fe, N. M.

was made "to spare the Japanese people from utter destruction."

When the ultimatum was rejected, the atomic bomb was sent into action.

"If they (the Japanese leaders) do not now accept our terms, they may expect a rain of ruin from the air, the like of which has never been seen on this earth," he said.

Mr. Truman revealed that "two great plants and many lesser works" employing more than 65,000 workers are producing the new atomic bomb. Even more destructive bombs are being developed, he said.

Oak Ridge One of Three Centers

Production centers are located at Oak Ridge, near Knoxville, Tenn.; at Richland, near Pasco, Wash.; and near Santa Fe, N. M.

Mr. Truman's statement, released while he still was en route home by cruiser from Potsdam, lifted the secrecy from one of the most closely-guarded enterprises of the war. No mention of atomic power or any possible use of it in warfare has been allowed under the newspaper and radio code of the Office of Censorship.

Mr. Truman did not reveal the effects of the first bomb used against Japan. He said, however, that despite the vast multiplied potency of the bomb, "the physical size of the charge is exceedingly small."

"It is an atomic bomb," he said. "It is a harnessing of the basic power of the universe."

"The force from which the sun draws its power has been loosed against those who brought war to the Far East."

Uranium Ore Used for Bombs

Stimson revealed that uranium is the essential ore in the production of the bombs. He added that "steps have

(See full page of Oak Ridge pictures on Page 17, and further details on Pages 2 and 18.)

been taken and will continue to be taken to insure adequate supplies of this mineral."

(Uranium is a "radioactive" chemical element. It belongs to the same family as radium. In radioactive elements the atoms slowly disintegrate by radiating energy, and in course of centuries one element is transferred into another.)

Stimson said "We are convinced that Japan will not be in a position to use an atomic bomb in this war."

"It is abundantly clear that the possession of this weapon by the United States, even in its present form, should prove a tremendous aid in the shortening of the war against Japan," Stimson said.

Stimson praised highly the scientists who had developed this atomic power.

"Behind these concrete achievements lie the tremendous contributions of American science," he declared. "No praise is too great for the unstinting efforts, brilliant achievements and complete devotion to the national interest of the scientists of this country. Nowhere else in the world has science performed so successfully in time of war."

The first atomic bomb presumably was dropped from a

Story of Secret Officially Told

Even Plant Chiefs Didn't Know What Work Others Did

Two Views of Giant Oak Ridge Production Plant

Brighter than a Thousand Suns

Brighter than a Thousand Suns

- The first atomic weapon that was made and detonated was known simply as *the gadget*.

- This photograph shows *the gadget* being prepared at the *Trinity test site* at Alamogordo in New Mexico.

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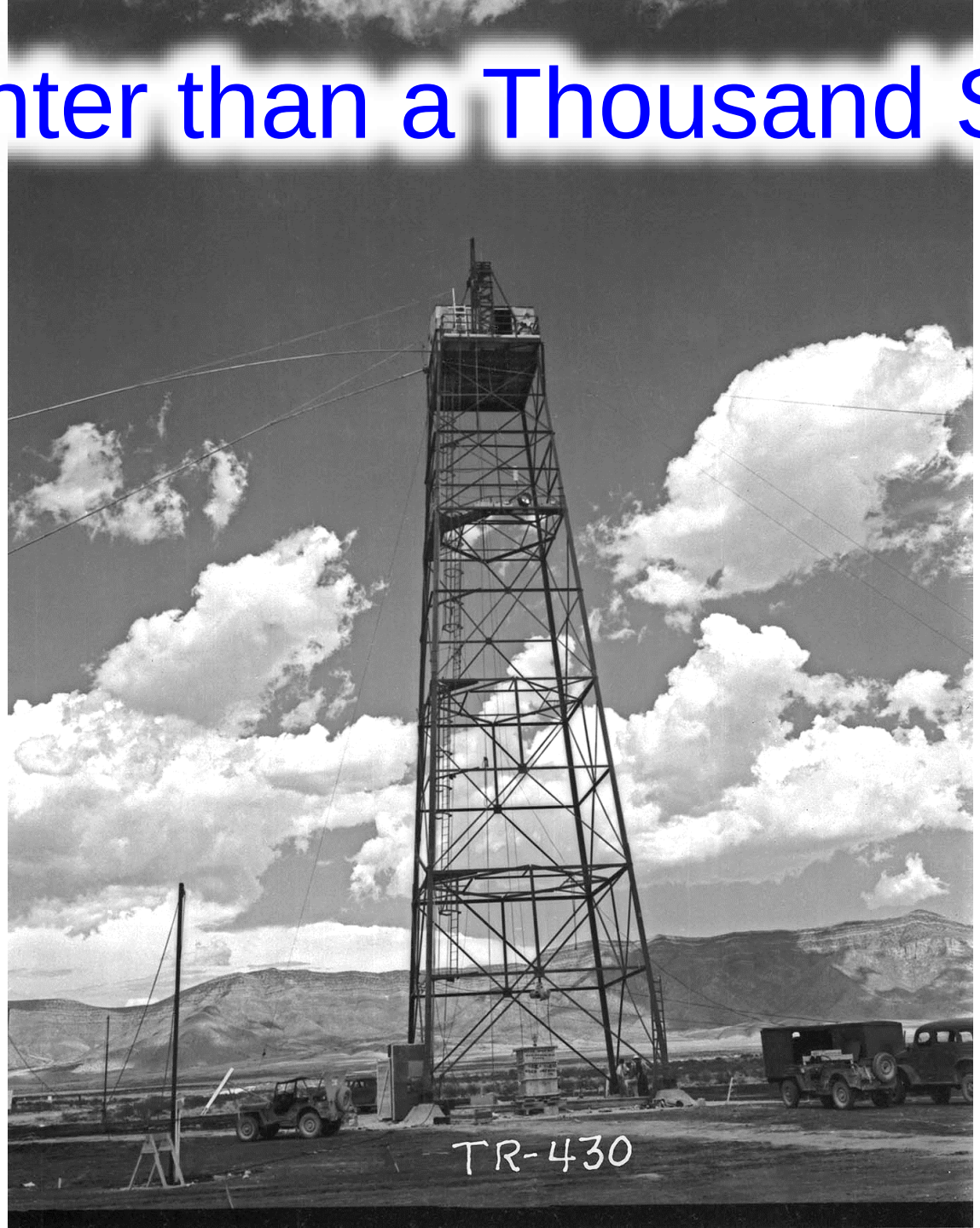

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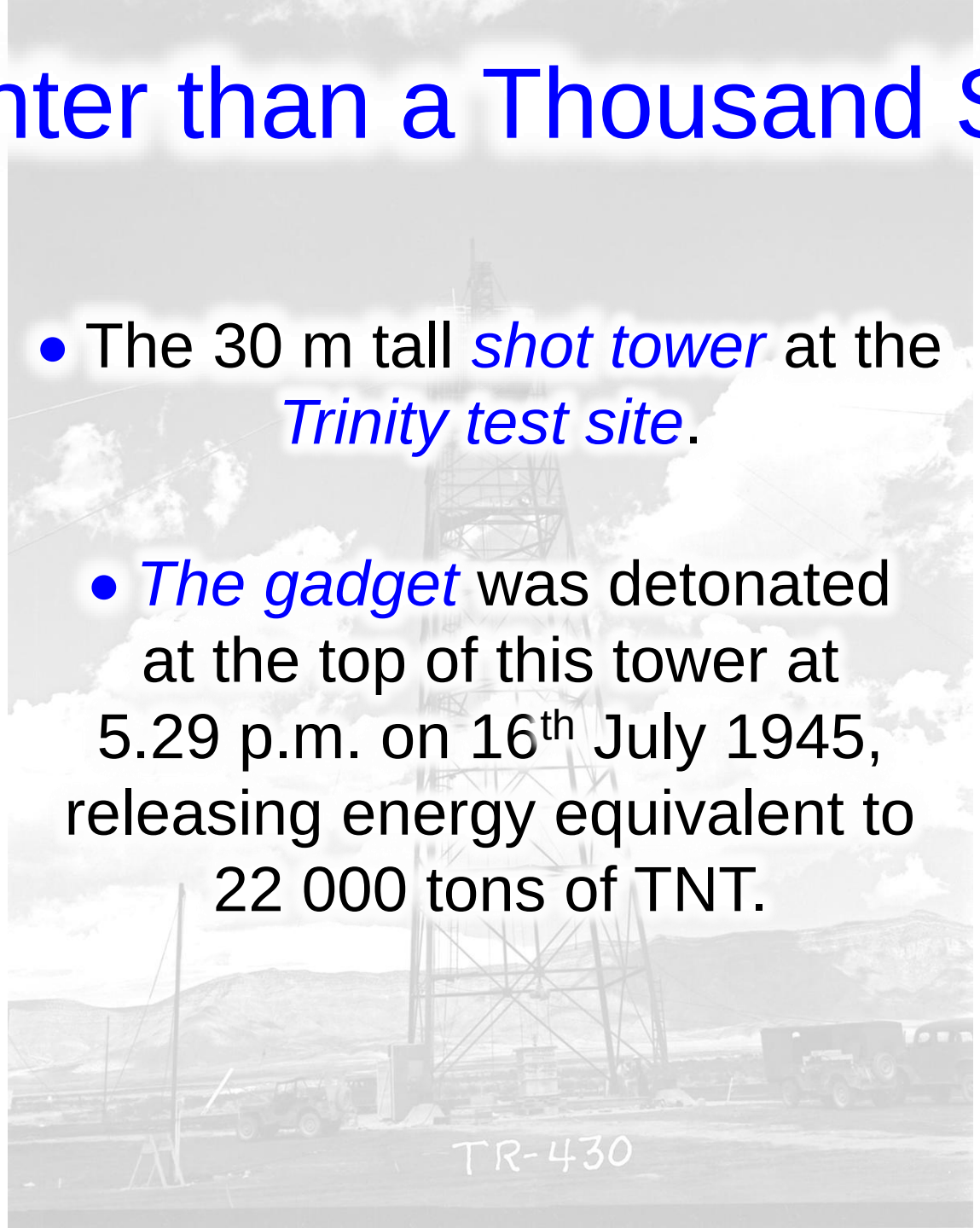
- The 30 m tall *shot tower* at the *Trinity test site*.

- *The gadget* was detonated at the top of this tower at 5.29 p.m. on 16th July 1945, releasing energy equivalent to 22 000 tons of TNT.



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- Trinity Site explosion, 0.016 second after explosion, 16th July 1945. The viewed hemisphere's highest point in this image is about 200 meters high.

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- The first test of a nuclear weapon was carried out on 16th July 1945. This photograph taken nine seconds after the *Trinity* detonation shows early formation of the familiar mushroom cloud.

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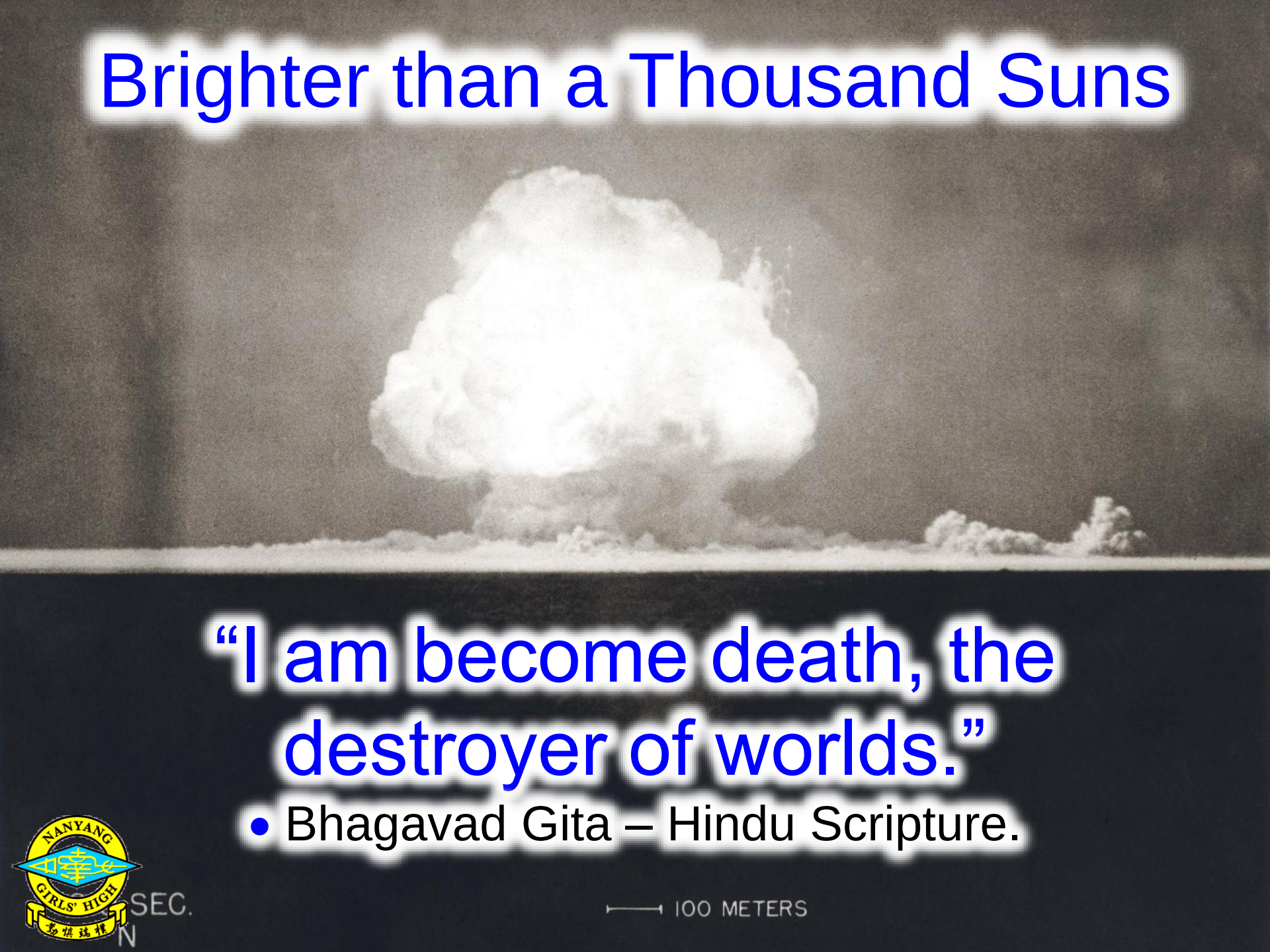

"I am become death, the destroyer of worlds."

- Bhagavad Gita – Hindu Scripture.

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"We knew the world would not be the same."

- Robert Oppenheimer.

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- Before the Trinity test, Physicists had to calculate whether or not energy released by detonating the world's first atomic bomb would *ignite the Earth's atmosphere*.

Brighter than a Thousand Suns

- Video: The Trinity test held on 16th July 1945 – 25 sec.
- Footage recorded approximately 9000 m away from the site of detonation.

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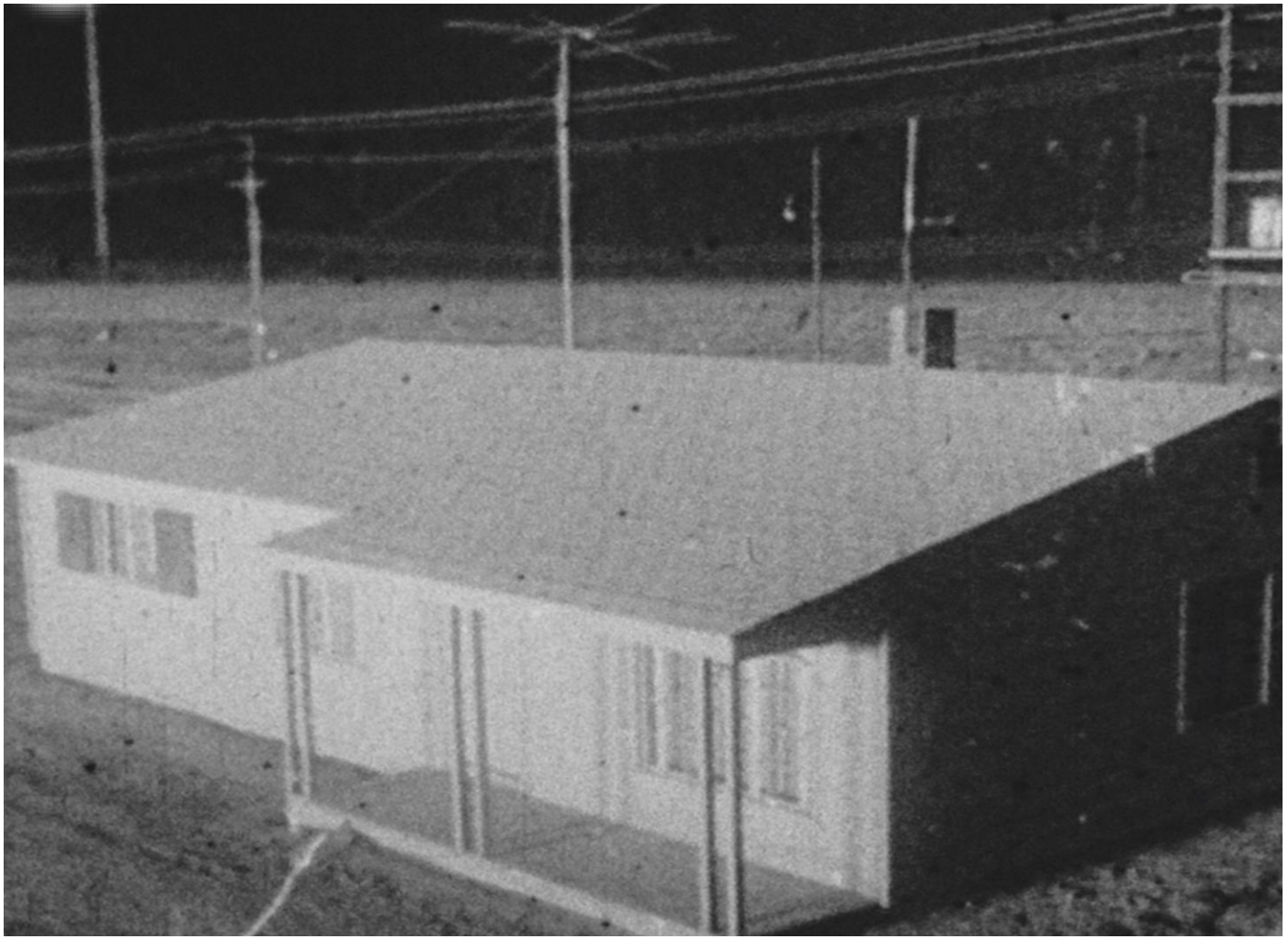

- Video: Effects of a Nuclear Explosion on a Building – 8 sec.

SECRET

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5/15/84

My Observations During the Explosion at Trinity on July 16, 1945 — E. Fermi

On the morning of the 16th of July, I was stationed at the Base Camp at Trinity in a position about ten miles from the site of the explosion.

The explosion took place at about 5:30 A.M. I had my face protected by a large board in which a piece of dark welding glass had been inserted. My first impression of the explosion was the very intense flash of light, and a sensation of heat on the parts of my body that were exposed. Although I did not look directly towards the object, I had the impression that suddenly the countryside became brighter than in full daylight. I subsequently looked in the direction of the explosion through the dark glass and could see something that looked like a conglomeration of flames that promptly started rising. After a few seconds the rising flames lost their brightness and appeared as a huge pillar of smoke with an expanded head like a gigantic mushroom that rose rapidly beyond the clouds probably to a height of the order of 30,000 feet. After reaching its full height, the smoke stayed stationary for a while before the wind started dispersing it.

- Enrico Fermi's description of the trinity test.

About 40 seconds after the explosion the air blast reached me. I tried to estimate its strength by dropping from about six feet small pieces of paper before, during and after the passage of the blast wave. Since, at the time, there was no wind I could observe very distinctly and actually measure the displacement of the pieces of paper that were in the process of falling while the blast was passing. The shift was about 2½ meters, which, at the time, I estimated to correspond to the blast that would be produced by ten thousand tons of T.N.T.

- Enrico Fermi's description of the trinity test.

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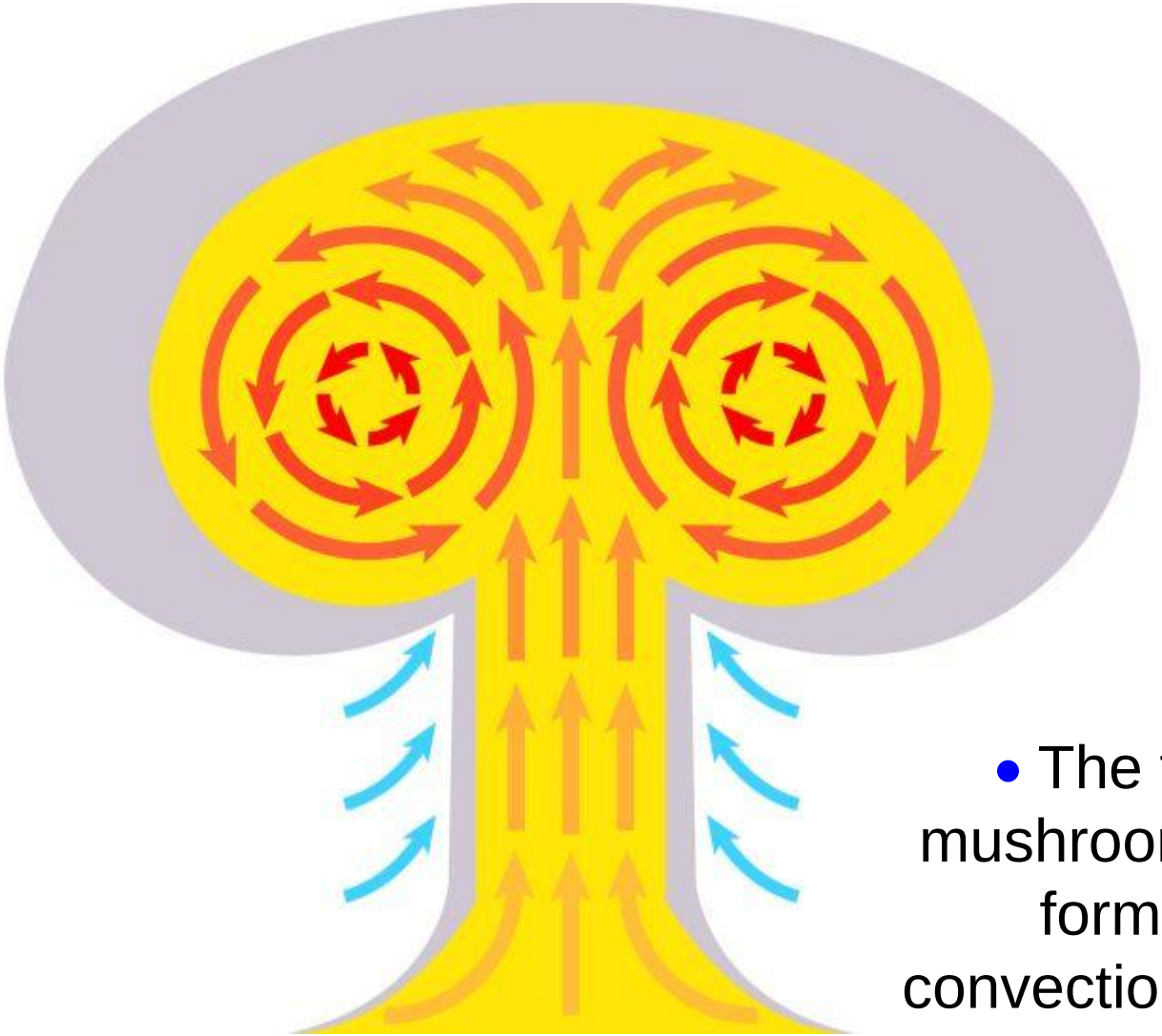

- The familiar mushroom cloud is formed by convection currents.

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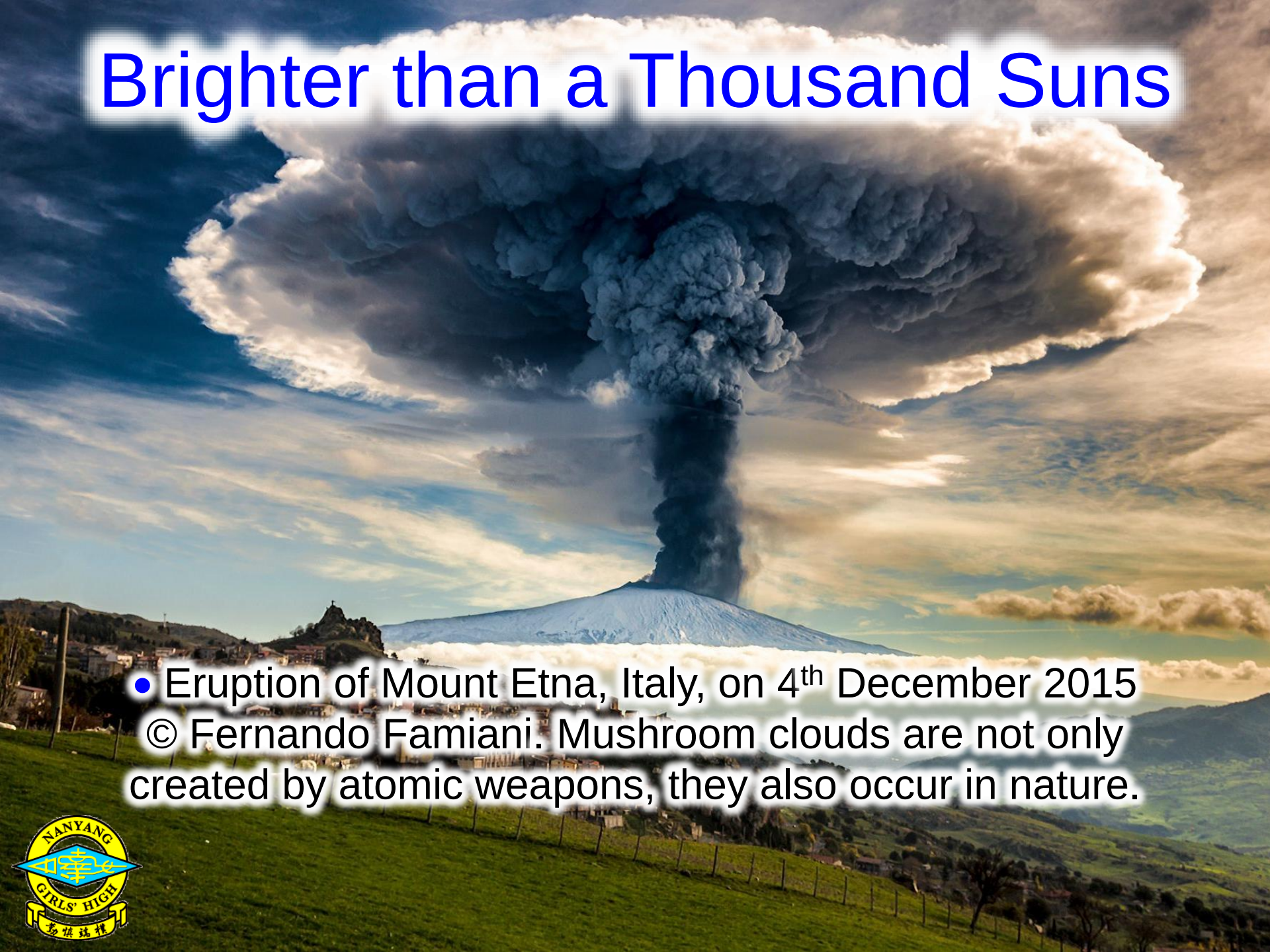

- Eruption of Mount Etna, Italy, on 4th December 2015

© Fernando Famiani. Mushroom clouds are not only created by atomic weapons, they also occur in nature.

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- Robert Oppenheimer (left) and Major General Leslie Groves (right) at the Trinity test site.

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- **Question:** How do you pack something the size of a nuclear reactor into something the size of a bomb that can be carried by an aircraft?

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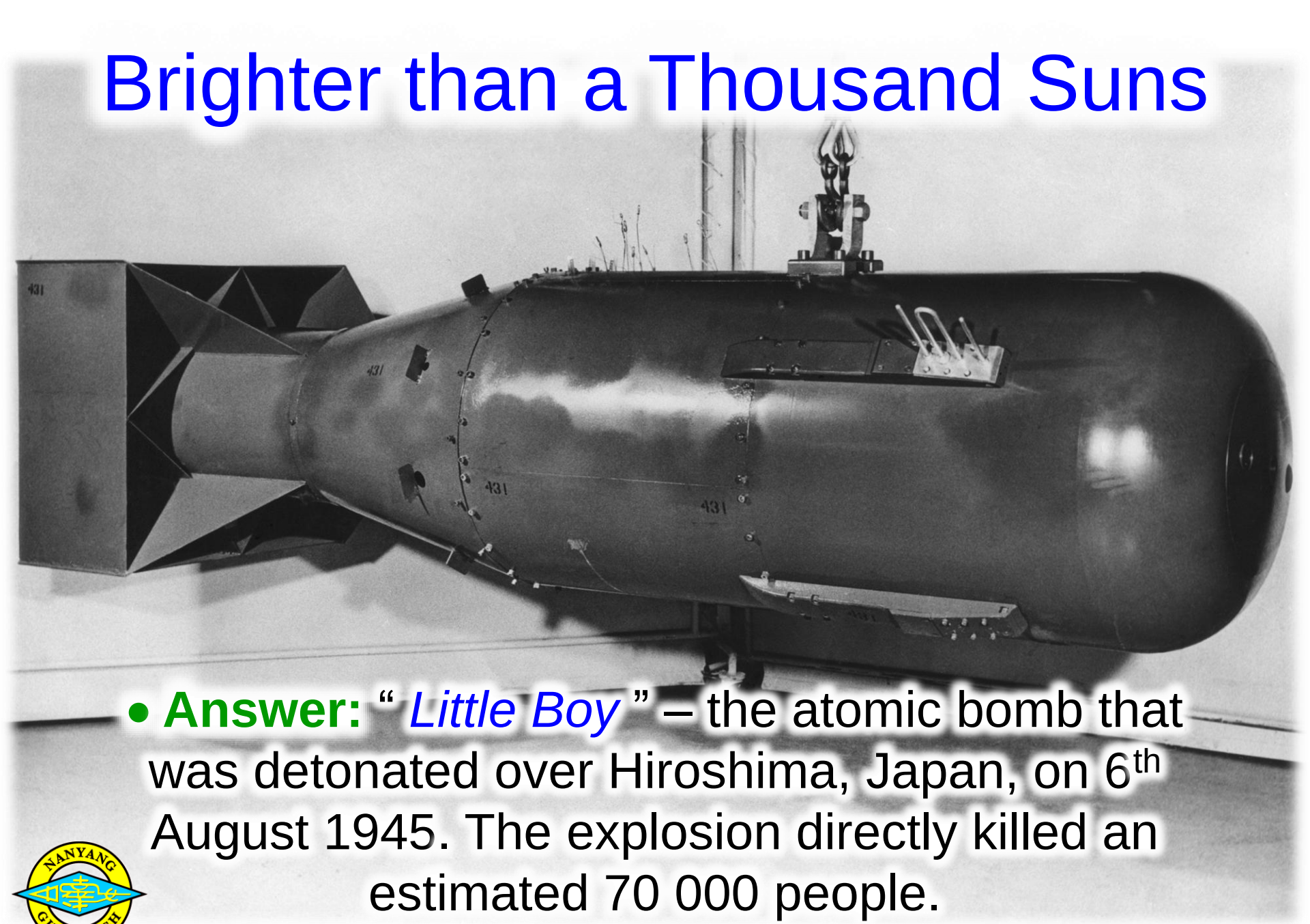

- **Answer:** "*Little Boy*" – the atomic bomb that was detonated over Hiroshima, Japan, on 6th August 1945. The explosion directly killed an estimated 70 000 people.

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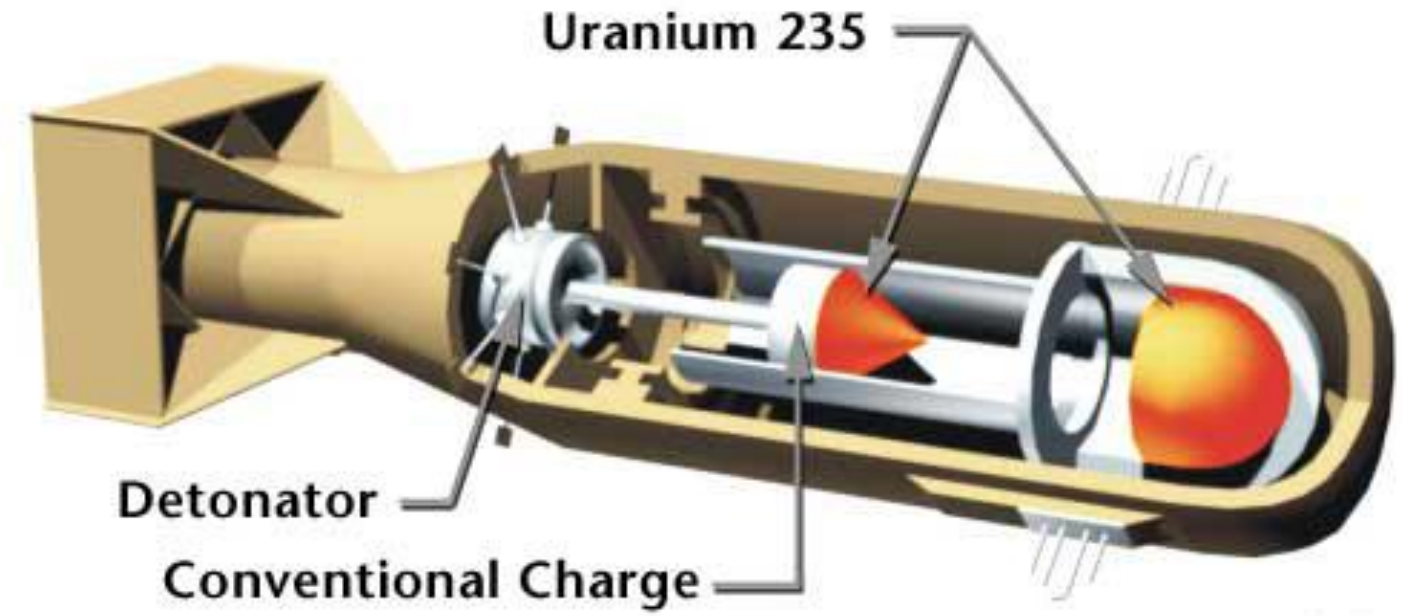

- "Little Boy" contained approximately 50 kg of enriched ^{235}U, which was detonated by a *gun-type* mechanism.

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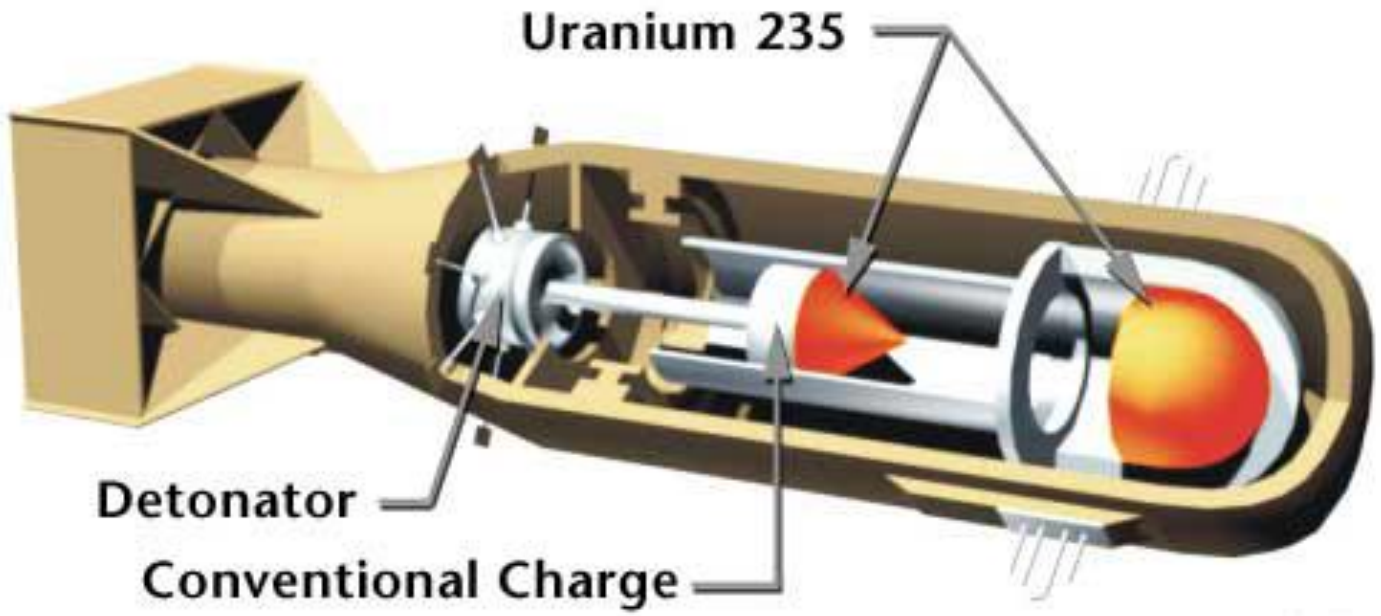

- One piece of ^{235}U was fired into a second piece of ^{235}U, with the two combined pieces exceeding the *critical mass* required for *sustained nuclear fission* to take place.

Brighter than a Thousand Suns

Brighter than a Thousand Suns

- Boeing B-29 Superfortress, *the Enola Gay*, photographed at an aviation museum in Virginia, USA.
- The pilot, Colonel Paul Tibbets, named the aircraft after his mother, Enola Gay Tibbets.
- The Enola Gay took off from the Northern Mariana Islands, a six hour flight time from Japan, accompanied by two other planes.
- Just in case the Enola Gay crashed on take-off, “Little Boy” was not armed for detonation until after the plane was in the air.

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- **Question:** Why was the aircraft silver, and not painted in camouflage colours?

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- **Answer:** The aircraft would have been close to the blast when the atomic bomb exploded. The aircraft's *silver coating would help to reflect the heat and radiation from the blast*, reducing any possible damage to the plane.

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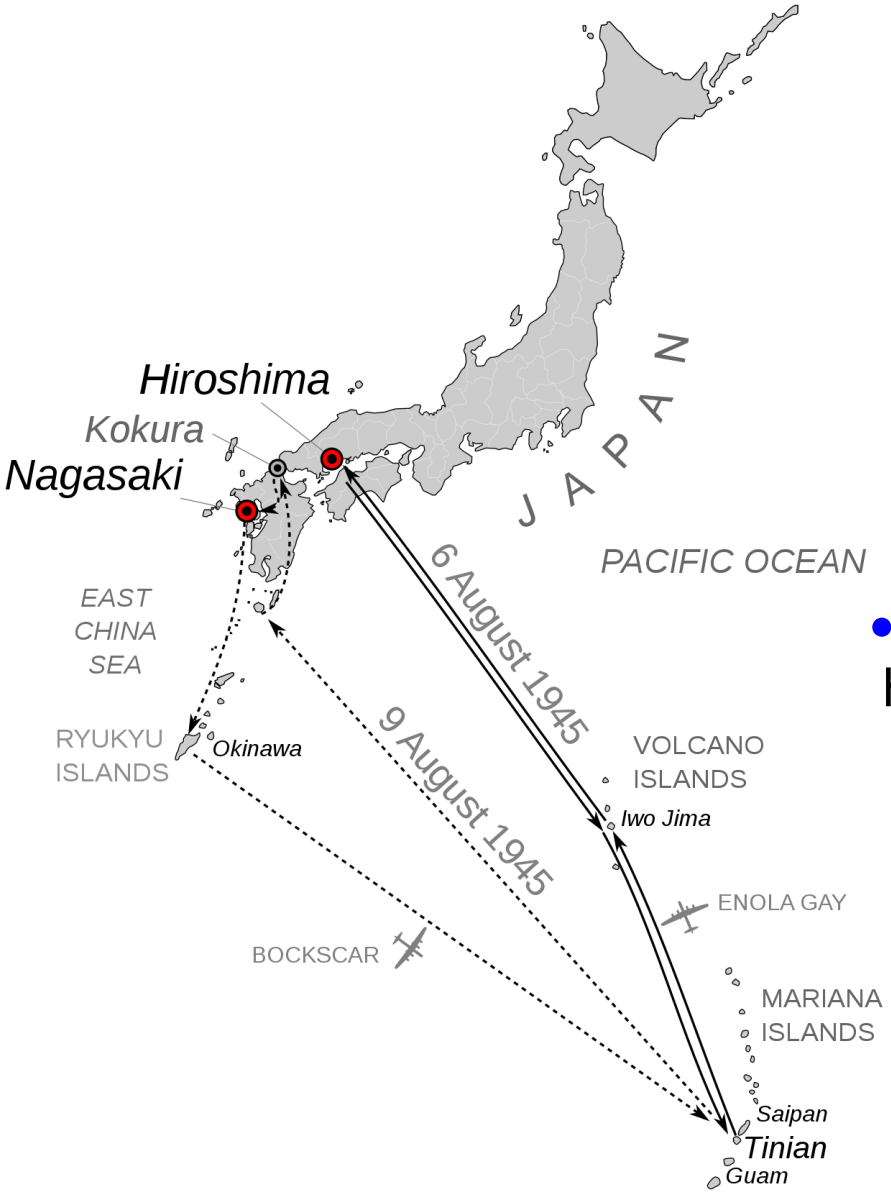
- Map of the routes flown by the B-29 bombers on 6th August 1945 (Hiroshima) and 9th August 1945 (Nagasaki).



- Three B-29s flew on each mission:
  - → Bomber.
  - → Instruments.
  - → Photography.
- The B-29s flew too high to be engaged by Japanese fighters and air defence.

Brighter than a Thousand Suns

Brighter than a Thousand Suns

- "Little Boy" was dropped over Hiroshima at 8.15 a.m. on 6th August 1945.

- The bomb fell for 44.4 seconds before it exploded 580 metres above the ground.

- The bomb was designed to explode *above the ground*, rather than on the ground, to reduce the amount of radioactive dust or *fallout*.

- The detonation of this single nuclear weapon released the same amount of energy as ~15 000 tons of conventional explosive.

Brighter than a Thousand Suns

"My God, what have we done?"

Captain Robert Lewis, Co-pilot of the Enola Gay.

"I pray no man will have to witness that sight again. Such a terrible waste, such a loss of life."

Captain Theodore van Kirk, Navigator of the Enola Gay.

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- **Question:** In what form(s) does the damage from an atomic bomb manifest itself?

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- **Answer:** The damage from a atomic bomb comes in three distinct forms:

1. *Blast* – the blast is the result of rapidly expanding hot air that has been heated by radiation. This pressure wave or shock wave travels out in all directions faster than the speed of sound (343 ms^{-1}).

2. *Fire* – the initial effect of the explosion is a blinding light, accompanied by radiant heat from the fireball. The Hiroshima fireball was 370 m in diameter, with a surface temperature of 6 000°C.

3. *Radiation* – fallout is dust and ash contaminated with highly radioactive fission products. Radiation can burn, and can cause mutations to DNA, leading to cancer.

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- Video: Hiroshima – Dropping the Bomb © BBC: 4 mins. 12 sec.

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- Hiroshima after the detonation of *Little Boy* on 6th August 1945.

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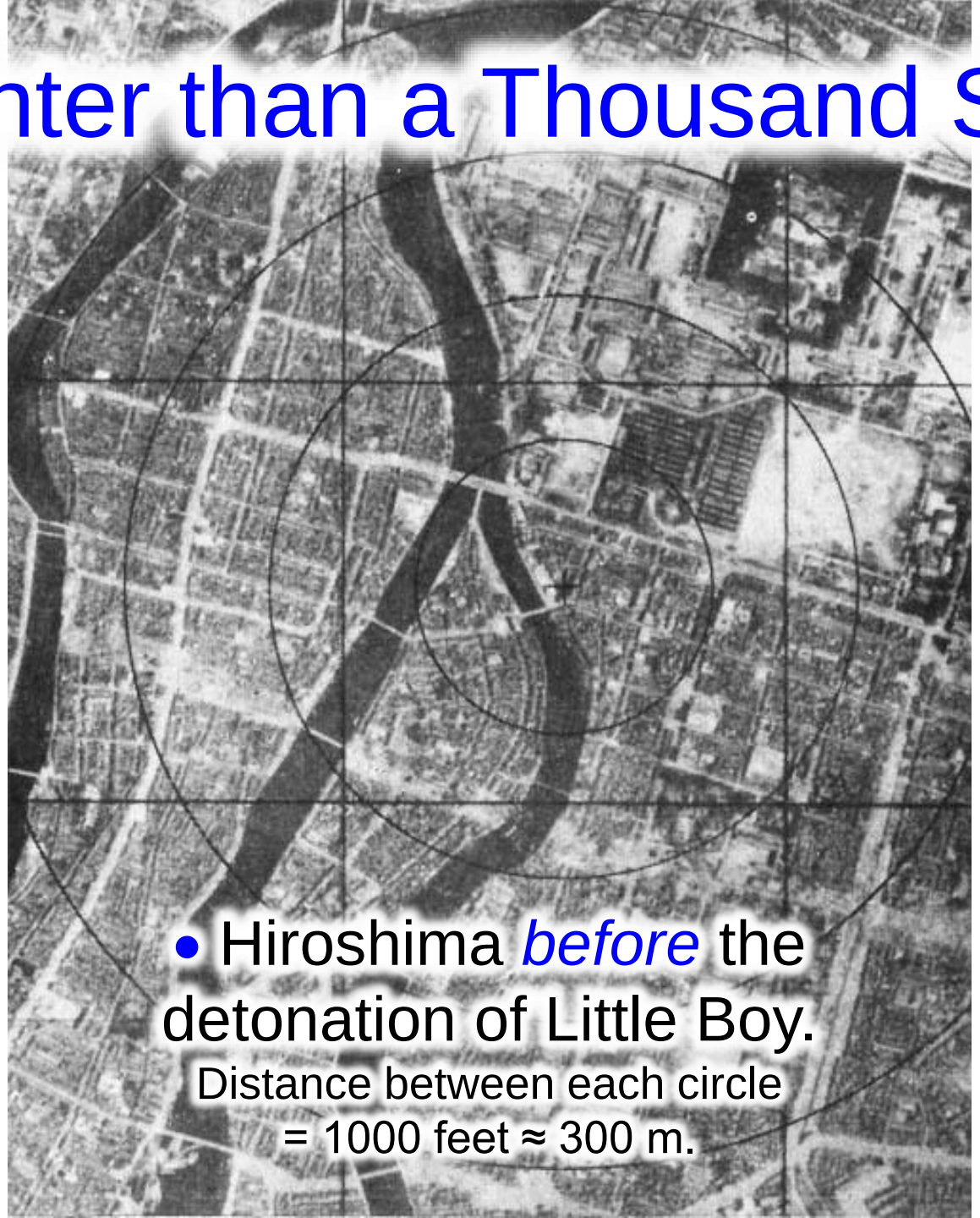

- Hiroshima *before* the detonation of Little Boy.

Distance between each circle = 1000 feet ≈ 300 m.

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- Hiroshima *after* the detonation of Little Boy.

Distance between each circle = 1000 feet ≈ 300 m.

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- The explosion at Hiroshima was recorded at *8.15 a.m.* on a wrist watch that was found in the ruins.

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- Wrecked framework of the Museum of Science and Industry in Hiroshima, Japan.

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- In December 1996, the building was added to the UNESCO World Heritage List as a reminder to the entire world of the horrors of the atomic bomb, and as a symbol of global peace.

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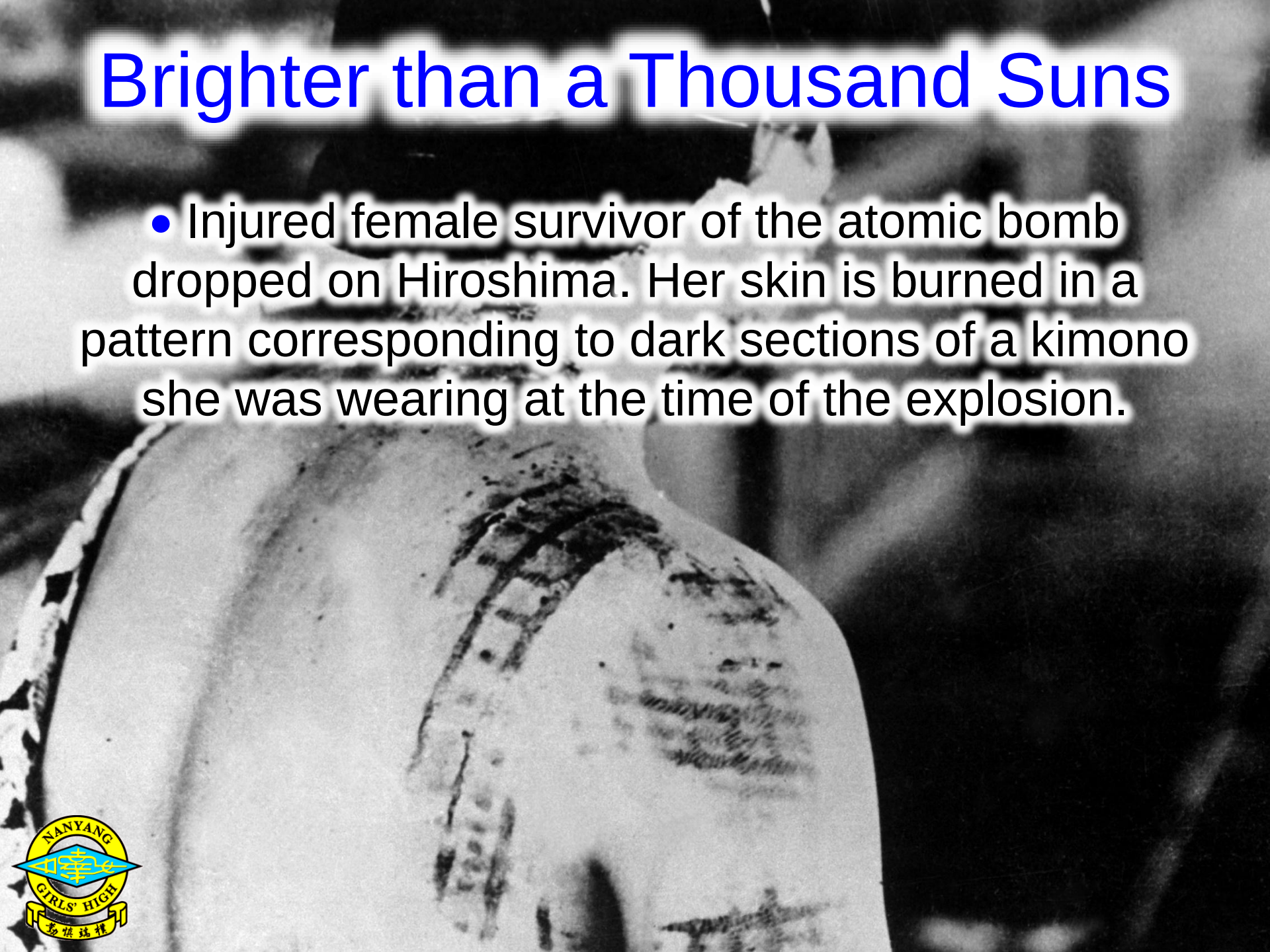

- Injured female survivor of the atomic bomb dropped on Hiroshima. Her skin is burned in a pattern corresponding to dark sections of a kimono she was wearing at the time of the explosion.

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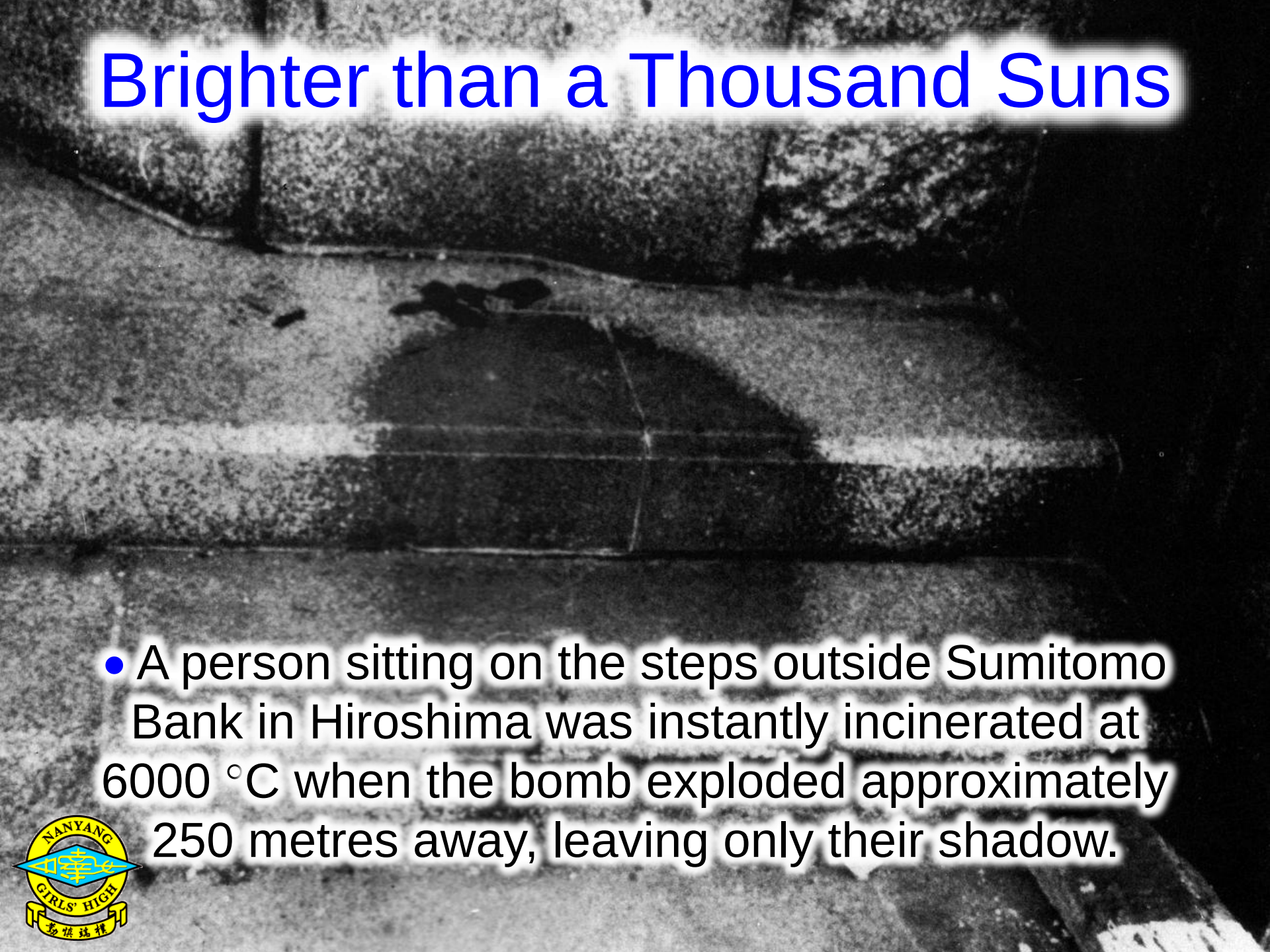

- A person sitting on the steps outside Sumitomo Bank in Hiroshima was instantly incinerated at 6000 °C when the bomb exploded approximately 250 metres away, leaving only their shadow.

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b. ATOMIC BOMB ON HIROSHIMA: The first brief description of the effects of the atomic bomb dropped on HIROSHIMA came to light on the 13th. August in advice from Tokyo to the Minister in Berne to the effect that

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the bomb exploded about 550 metres above the ground. Thereafter there was a yellow glare followed by intense heat and the collapse of buildings which caught fire a half to an hour afterward. At 500 metres, the blast exposed peoples' entrails and started their eyeballs from their sockets. People were killed by the blast 2000 metres away, but others in log-covered trenches remained unharmed. Up to 2000 metres from the explosion people were stripped stark naked and burnt to death. Wooden buildings up to 4000 metres away were [illegible] destroyed, while at the same distance most people were burned. Even as far away as 7000 metres people and vegetation were slightly burned.

- Declassified top secret document that describes the effects of the atomic bomb dropped on Hiroshima.

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- General Carl Spaatz decorates Tibbets with the Distinguished Service Cross after the Hiroshima mission.

- By United States Air Force - Air Force Historical Research Agency, Public Domain, https://commons.wikimedia.org/w/index.php?curid=28022444

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- Brigadier General Paul W. Tibbets Jr. (1915 – 2007)

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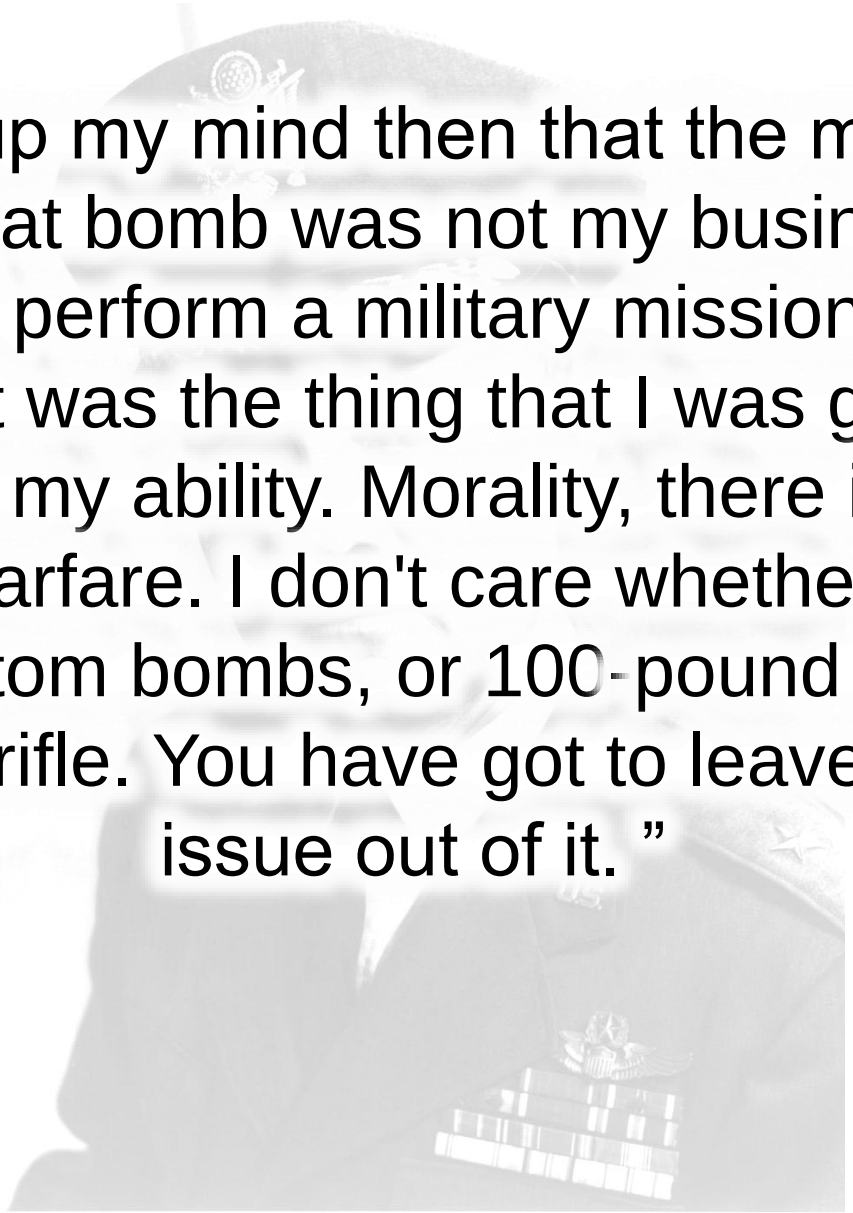
“ I made up my mind then that the morality of dropping that bomb was not my business. I was instructed to perform a military mission to drop the bomb. That was the thing that I was going to do the best of my ability. Morality, there is no such thing in warfare. I don't care whether you are dropping atom bombs, or 100-pound bombs, or shooting a rifle. You have got to leave the moral issue out of it. ”



- Brigadier General Paul W. Tibbets Jr. (1915 – 2007)

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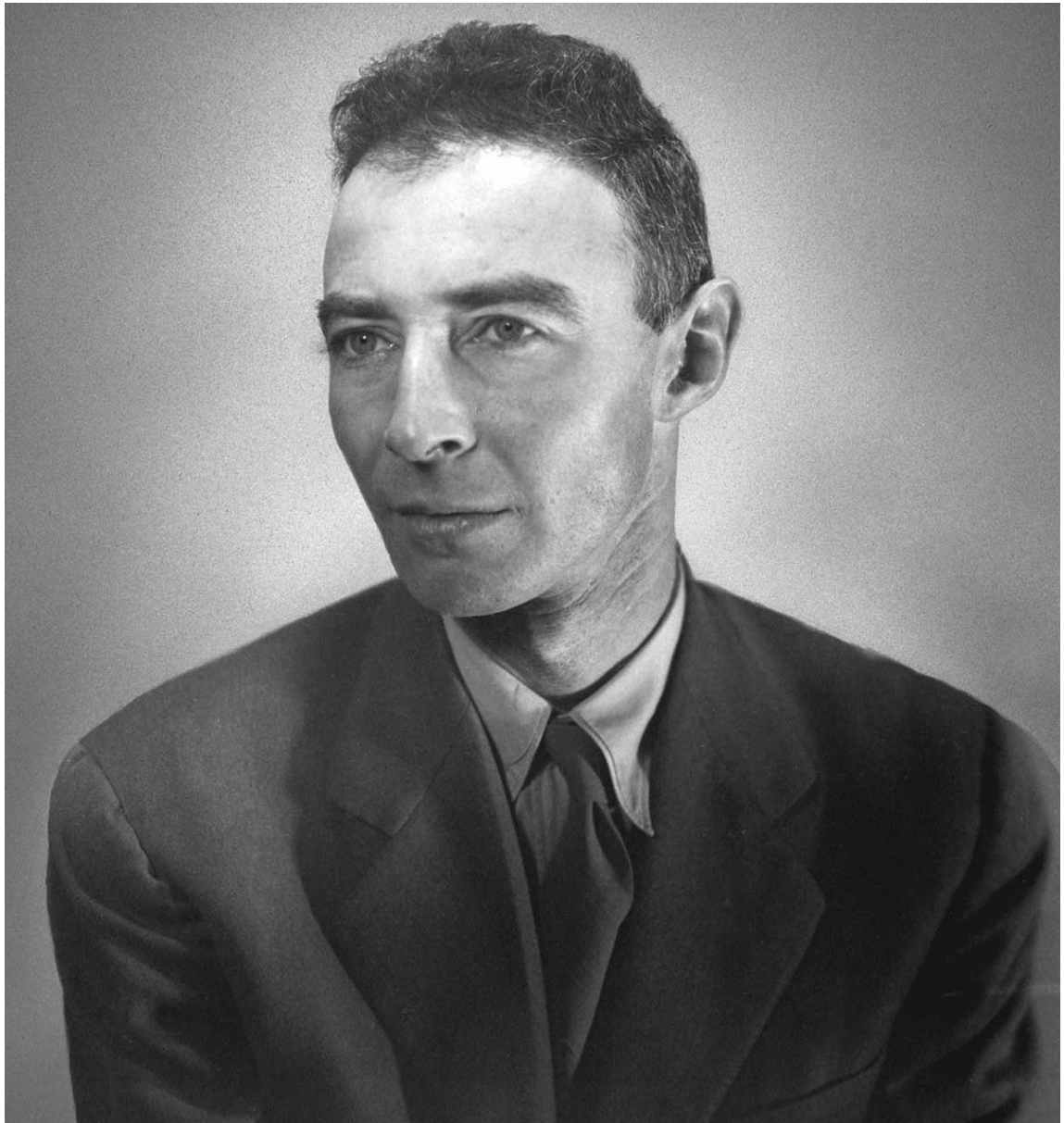

- Robert Oppenheimer (1904 – 1967)

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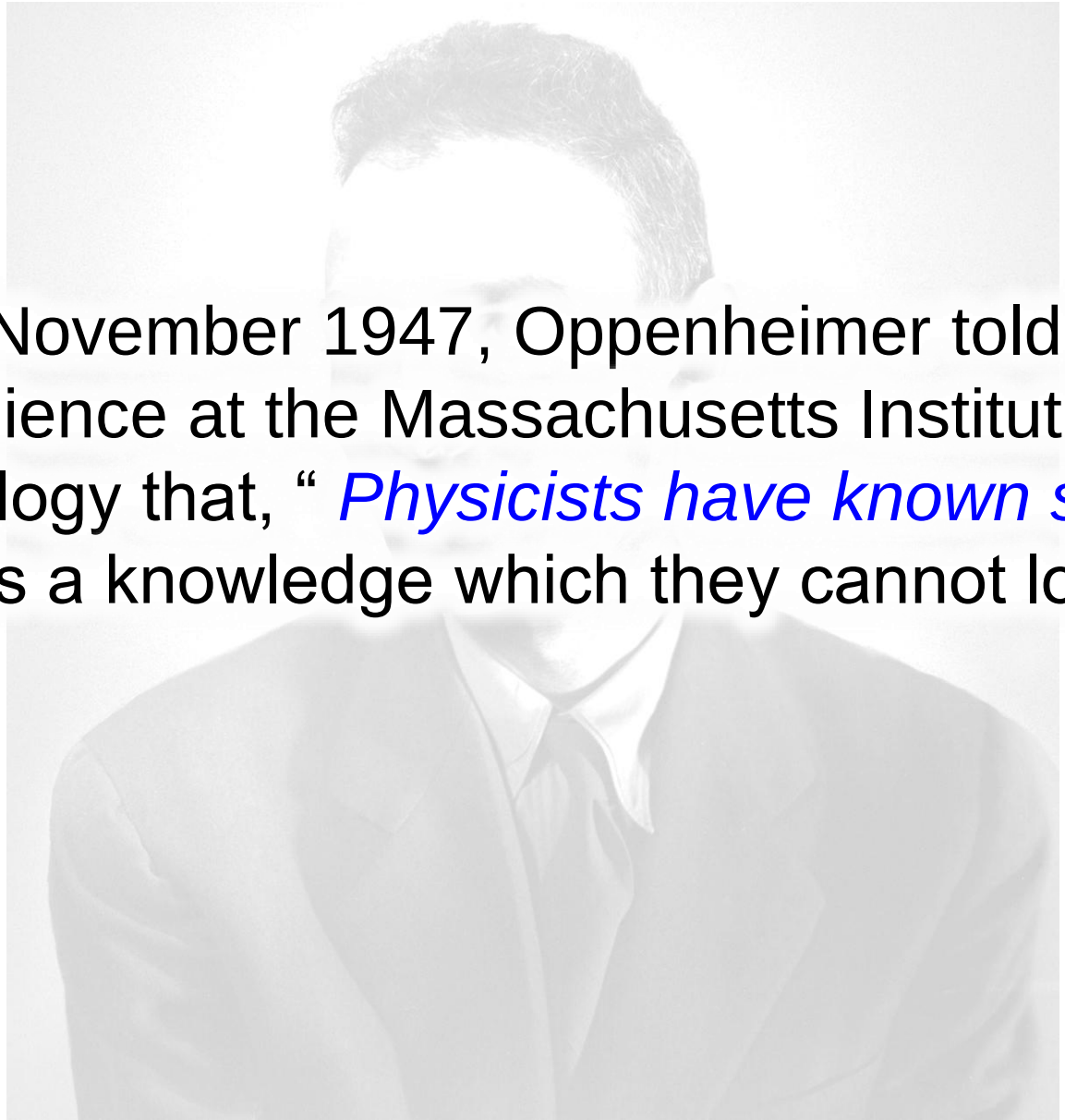

In November 1947, Oppenheimer told an audience at the Massachusetts Institute of Technology that, “ *Physicists have known sin*, and this is a knowledge which they cannot lose. ”

- Robert Oppenheimer (1904 – 1967)

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Freeman Dyson, an English Physicist, thought carefully about Oppenheimer's expression of guilt.
" The sin of the Physicists at Los Alamos did not lie in their having built a lethal weapon. They did not just build the bomb. *They enjoyed building it*. They had the best time of their lives building it. That, I believe, is what Oppenheimer had in mind when he said that they had sinned. "

- **Question:** Why would the Scientists involved in the Manhattan Project have enjoyed building the atomic bomb?

- Robert Oppenheimer (1904 – 1967)

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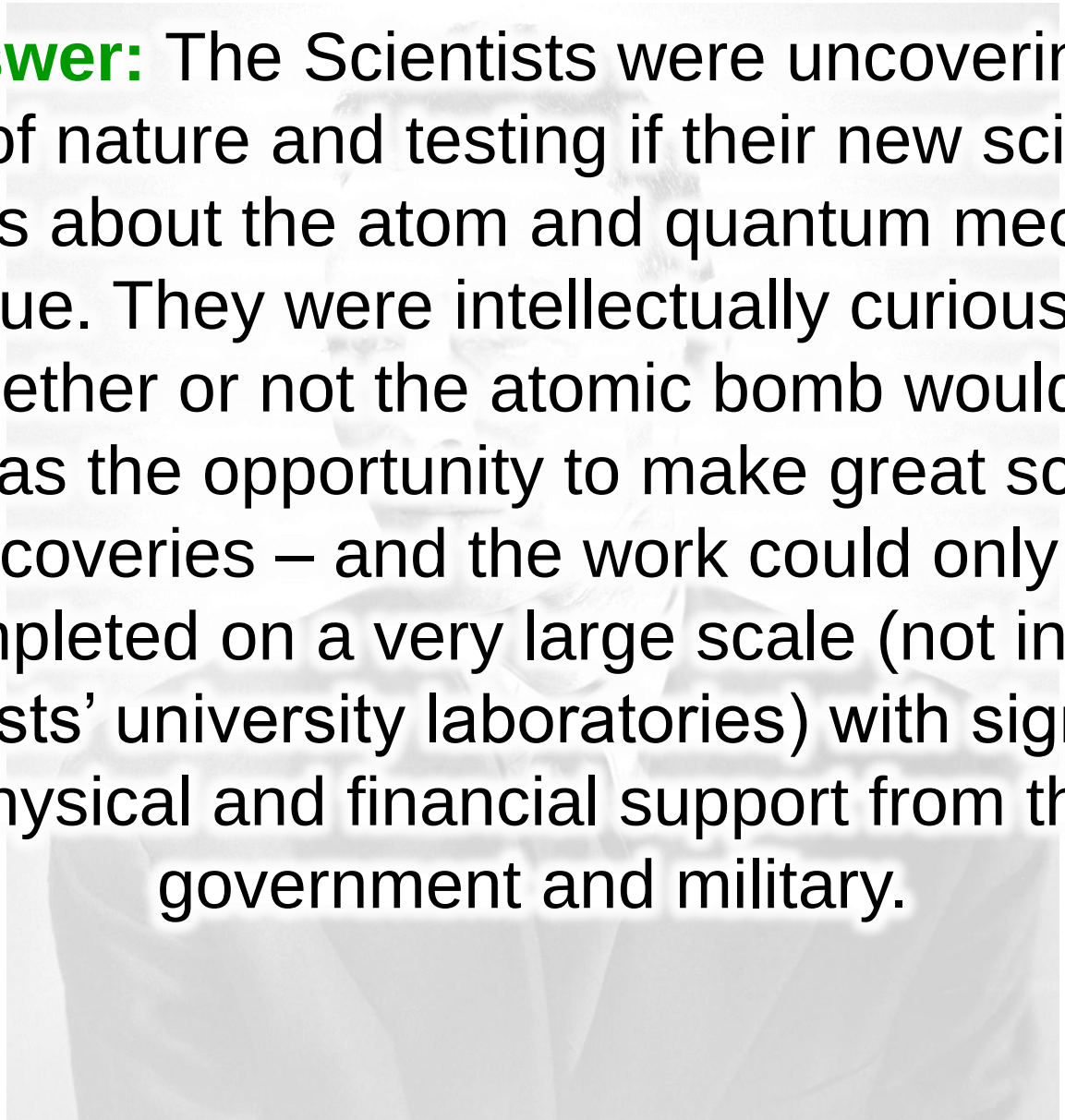
- **Answer:** The Scientists were uncovering the laws of nature and testing if their new scientific theories about the atom and quantum mechanics were true. They were intellectually curious to find out whether or not the atomic bomb would work. This was the opportunity to make great scientific discoveries – and the work could only be completed on a very large scale (not in the Scientists' university laboratories) with significant physical and financial support from the government and military.



- Robert Oppenheimer (1904 – 1967)

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1. What events mark key moments in human history?

2. What drives scientific innovation? Would the Manhattan Project have taken place during peacetime?

3. How could people of conscience create weapons of mass destruction?

4. What is the purpose of Science?

5. What responsibilities does Science have to society?

6. Who determines what Science should do?

7. What are some positive outcomes from research into atomic weapons?

8. Is it acceptable to do Science for the sake of curiosity, without any care for the consequences?

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Make Your Thinking Visible

- **Individual:** Write a general statement (*generalisation*) to illustrate what you now understand about scientific progress and how it influences humanity.

- Try to use the conceptual lenses *conflict* and *change* in your statement.

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Make Your Thinking Visible

- **Discussion:** What were the consequences of America's of bombing Hiroshima and Nagasaki using nuclear weapons?

- Short term.
- Long term.
- Environmental.
- Global.
- Political.

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

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Make Your Thinking Visible

- **Discussion:** What other events have occurred in human history after which, "*We knew the world would not be the same*"?

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

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Make Your Thinking Visible

- **Discussion:** "The research and development of nuclear weapons by America and her allies has been detrimental to humanity."

- Give two or three points in support.
- Give two or three points against.
- Your conclusion.

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

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Make Your Thinking Visible

- Key moments in human history are marked by significant technological or scientific events. For example, the iron age, nuclear age, space age, information age.

- Conflict drives scientific innovation, leading to significant advances in human knowledge that may benefit humanity. For example, the development of the atomic bomb during World War II and the Space Race during the Cold War.

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- Robert Oppenheimer

- Accident at the Manhattan Project

- The Bomb Marker Inside Your Body

- BBC News Article: Robert Oppenheimer:
https://www.bbc.com/future/article/20230712-robert-oppenheimer-manhattan-project-nuclear-scientist-atomic-bomb

- BBC News Article: A Fatal Accident at the Manhattan Project
https://www.bbc.com/future/article/20230719-the-blue-flash-louis-slotin-accident-manhattan-project-oppenheimer-atomic-bomb

- BBC News Article: The Atomic Bomb Marker Inside Your Body:
https://www.bbc.com/future/article/20230808-atomic-bomb-spike-carbon-radioactive-body-anthropocene

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References

- Images taken from ShutterStock: https://www.shutterstock.com
- Images taken from Science Photo Library: https://www.sciencephoto.com
- Video simulating a nuclear chain reaction produced by Prof. Bassam Shakhashiri.
- Information taken from:
  - → https://www.atomicheritage.org
  - → https://en.wikipedia.org/wiki/little_boy
  - → https://en.wikipedia.org/wiki/manhattan_project
  - → Bizony, P. (2007). *Atom*. Cambridge: Icon Books Ltd.

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Presentation on:

Brighter than a Thousand Suns:
A Scientific Perspective on the History of the Atomic Bomb

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Presentation Created 5th March 2019
Updated 25th February 2021 and 14th May 2025

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- Video: Orchestral Manoeuvres in the Dark – Enola Gay – 6 mins 40 sec.

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- This is an interdisciplinary lesson fusing History and Science. Students will learn that the end of World War II in the Asia-Pacific region was the result of dropping atomic bombs on Hiroshima and Nagasaki. Beyond learning about the atomic bomb being a significant turning point in the war, students will also learn how the bomb could be a terrible invention that brings great destruction, but in the long-run, it also brings great benefits to humankind.